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DIRECTOR NOTES

This issue marks the end of a decade of publication of this **DIGEST**. During that time we have seen a number of changes in style and content. These changes have been introduced in part to reflect changing technological emphasis, but mostly to serve the informtion needs of the reader more effectively. The indications are that we have been at least partially successful in our efforts, since your response as readers has been generally favorable. In spite of this, we are well aware that there is always room for improvement. I look forward to a flow of constructive suggestions during the coming year. Whenever possible we will use those suggestions to advantage.

We have not been without our problems. The cost of preparing and distributing the **DIGEST** has increased markedly. We have therefore been required to increase the subscription price to one hundred dollars for the coming year for domestic delivery. Our foreign subscriptions are increased accordingly. It is my expectation that the readers will continue to find the **DIGEST** a prudent investment. Wisely purchased, information is still one of the cheaper commodities on today's market.

During the coming year, we at SVIC plan to issue some interesting publications. I am pleased to announce the first of these, "An International Survey of Shock and Vibration Technology," which will be available for distribution early next year. This report may well be the first of its kind. It is a very broad survey of the complete shock and vibration technology from an international viewpoint. A more complete announcement, along with price, is expected to be given in the January **DIGEST.** Other publications will be announced as they are about to become available.

The encouragement of the shock and vibration community over our many years of service has been gratifying. I look upon 1979 as a new and exciting year of challenge. With your continued support, we will meet that challenge.

H.C.P.

EDITORS RATTLE SPACE

THE ADVANCE OF TECHNOLOGY

This issue of the DIGEST marks the end of ten years of publication. During this time the abstracts of almost 20,000 papers, reports, and theses have been published. In addition, more than 200 feature and review articles have appeared. It is an appropriate time to pause and reflect upon the focus of these technological advances -- that is, are they concerned mostly with solving problems or with understanding basic phenomena and environments in vibration and shock?

The abstracts of the past ten years indicate that problems are being studied in ever greater detail but that there has been little accomplished in understanding basic phenomena or developing new techniques. In my opinion this trend is a result of the evaluation of the digital computer as a practical tool for solving engineering problems. In fact the major advances in shock and vibration technology have been in the electronics area -- digital computers for mathematical computation, data handling, and data analysis; and instrumentation for measurement, data analysis, and data display.

The digital computer stimulated work aimed at perfecting numerical methods. For example, the finite element method was developed for solving practical engineering problems in machines and structures. This method has been extended to many physical problems by the development of specific "elements" to represent its physical behavior. The numerical methods used to manipulate equations are thus a by-product of finite element work. Developments of the past ten years have provided the tools for solving most dynamics problems.

The second major area of technological advancement has to do with measurement and data processing. New high response sensors, including proximity probes and accelerometers, allow measurement of vibration and shock phenomena in all frequency ranges. These devices have greatly simplified measurement and made it less of an art. The fast Fourier analyzers have advanced data processing far beyond our expectations. All of this technology is applicable to solving current problems.

What about the advances in the next ten years? In my opinion they will involve digital computers -- the development of more practical minicomputers and desk computers. Not only computation will be done on the minicomputer but also much data processing for machine monitoring and diagnostics. Research in understanding basic phenomena is lagging and will continue to do so. Evolution of technology to solve practical problems has been adequate, but it has tended to create an atmosphere in which no one is interested in understanding basic physics other than that absolutely necessary to solve a problem.

R.L.E.

SHOCK AND VIBRATION ANALYSIS USING FINITE ELEMENT TECHNIQUES

T.V. Seshadri*

Abstract - This paper reviews current state of the art in shock and vibration analyses using finite element techniques. The development of a total finite element model using a combination of analytical and experimental techniques is described.

The finite element technique consists of dividing a continuum into a number of discrete elements and imposing conditions (force and displacement compatibilities) at points shared by the elements. These points are called joints or nodes. The increasing use of finite element techniques is largely due to the advancement in sophisticated digital computers. Several finite element codes are available from various sources. Most of these codes use the so-called stiffness method as opposed to the flexibility method.

In the stiffness method, the matrix equation for static force is written as

$$\{F\} = [K]\ \{x\} \tag{1}$$

where

$\{F\}$ = column force vector
$[K]$ = square stiffness matrix
$\{x\}$ = column displacement vector

By setting $\{x\}$ equal to unity the stiffness matrix represents the force required to cause unit displacement.

For a uniform bar with two joints at each end, as shown in Figure 1, the stiffness matrix can be written as

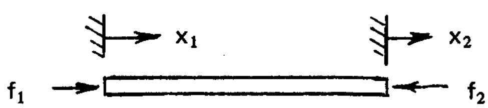

Figure 1. Uniform Bar with Two Nodes

*Fruehauf Corporation, Detroit, Michigan

$$[K] = \frac{EA}{L}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \tag{2}$$

The stiffness matrix can be obtained by assuming a unit displacement in one degree of freedom (keeping all other displacements zero) and finding the force required to cause that unit displacement. Several textbooks on finite element method discuss in detail the calculation of stiffness matrices. The fundamentals have been explained thoroughly [1].

In dynamic analysis, two additional terms -- mass and damping matrices -- are needed. The mass matrix can be found in different ways. For example, if the mass m for a uniform bar is lumped at the two nodes (Fig. 2) the mass matrix becomes

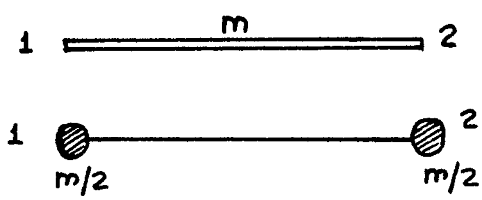

Figure 2. Lumped Mass of Uniform Bar

$$[M] = \begin{bmatrix} m/2 & 0 \\ 0 & m/2 \end{bmatrix} \tag{3}$$

If the bar is divided into two elements with three nodes or joints, the lumped mass assumption yields a mass matrix

$$[M] = \begin{bmatrix} m/3 & 0 & 0 \\ 0 & m/3 & 0 \\ 0 & 0 & m/3 \end{bmatrix} \tag{4}$$

Thus the lumped mass approach always gives a diagonal mass matrix. A diagonal matrix is one in which elements other than the main diagonal are zero. Such a matrix has several important advantages; computer dynamic analysis involves reducing non-diagonal matrices into diagonal ones. The lumped mass approach is not accurate, however, and the structure may have to be divided into a large number of elements to yield reasonable results.

Another method for finding the mass matrix is the consistent mass approach, so called because the mass matrix is derived using the same displacement function as the stiffness. Take, for example, the longitudinal bar; using a consistent mass the mass matrix becomes

$$[M] = \begin{bmatrix} m/3 & m/6 \\ m/6 & m/3 \end{bmatrix} \qquad (5)$$

This is a non-diagonal matrix and is a better representation of the actual mass distribution than a diagonal matrix. The mass matrices obtained either by lumped or consistent mass are independent of frequency.

Yet another method, called distributed mass, uses exact mathematical expressions for mass distribution. The method yields better results, but the mass and stiffness matrices are functions of frequency. They will therefore involve considerable computer costs and are thus not economical.

The general dynamic equations of motion for an n degree of freedom system in matrix form is

$$[M]\left\{\ddot{x}\right\} + [C]\left\{\dot{x}\right\} + [K]\left\{x\right\} = \left\{f(t)\right\} \qquad (6)$$

The solution techniques depend on the nature of f(t). The techniques have been described in detail [1]. Some particulars of those techniques are described below.

FREE VIBRATION OR MODAL ANALYSIS

Before describing the solution techniques for free vibration analysis or modal analysis, it is worthwhile to define modal analysis.

The term modal analysis has become especially popular with empirical vibration engineers. Modal analysis, either analytically or empirically, involves finding the natural frequencies and mode shapes of a structure under free-free conditions. (Free-free conditions can be obtained by supporting the structure on very soft springs.) Various types of test equipment are available to determine the modal properties of a structure. Analytical modal analysis is discussed below; empirical modal analysis is also briefly explained.

The undamped free vibration equation of a system, using lumped or consistent mass, will be

$$[M]\left\{\ddot{x}\right\} + [K]\left\{x\right\} = 0 \qquad (7)$$

using harmonic response

$$\left\{x\right\} = \left\{X\right\}e^{j\omega t} \qquad (8)$$

the matrix equation becomes

$$(-\omega^2 [M] + [K])\left\{X\right\} = 0 \qquad (9)$$

For non-trivial solution of equation (9), the condition to be satisfied is that the determinant should vanish.

$$|-\omega^2 [M] + [K]| = 0 \qquad (10)$$

This is called an eigenvalue problem; the vector $\left\{X\right\}$ associated with each frequency ω -- called the eigenvector -- is the mode shape.

Several solution techniques are available, the most common of which are determinant tracking, the Jacobi method, the Givens method, and the Householder method. In the determinant tracking method the value of the determinant in equation (10) is calculated for several trial frequencies. When there is a change in sign of the determinant, the determinant is recalculated using a new trial frequency until a specified tolerance level is reached. This method will work well except in some cases with closely spaced natural frequencies (Fig. 3).

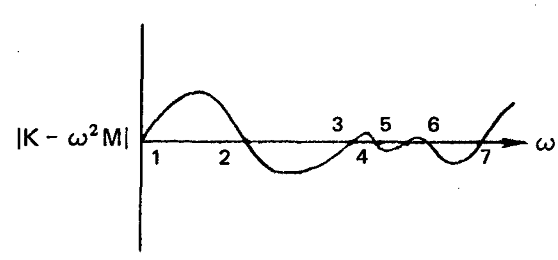

Figure 3. Determinant Tracking Method

One or two roots between 4, 5, and 6 may be missed. This difficulty is eliminated by using the Sturm sequence property, which determines the number of roots below any frequency. Actually, the determinant equation (10) is a polynomial equation, and the number of real roots between any two numbers, which are not roots, can be found. The method involves tri-diagonalization of the matrix ($[K] - \omega^2 [M]$); i.e., maximum non-zero terms in a row is 3, one diagonal and two adjacent terms. The values of several pre-defined expressions are calculated, and the sign changes are noted. For example, if N(a) is the number of sign changes for value 'a' and N(b) is the number of sign changes for value 'b', the number of real roots between 'a' and 'b' is N(a)−N(b). Therefore, closely spaced roots cannot be missed. However, the Sturm sequence does not recognize multiple or repeated roots.

The Jacobi method involves taking the largest absolute value of the non-diagonal matrix and applying several orthogonal transformations. The product of these transformation matrices reduces the original matrix to a diagonal matrix even if there are multiple roots. The sequence of transformations, sometimes called rotations, is infinite, though convergent, and the sequence can be terminated depending on the required precision. The eigenvalues will be the elements of the diagonalized matrix.

In the method of Givens, a finite sequence of orthogonal transformations is performed, but the original matrix is reduced to a tridiagonal form. A numerical technique is combined with the Sturm sequence property to obtain all the eigenvalues.

The method of Householder also produces a matrix of tri-diagonal form but with an increase in efficiency and economy as compared to Givens method. For an n x n matrix, (n−2) transformations are required although each might involve more calculations than the Givens method.

SUBSTRUCTURING

In complex structures for which the finite element method is used, the number of equations to be solved is large and requires a large computer core. A few years ago Guyan developed a technique -- now known as the Guyan reduction -- to reduce the number of equations by partitioning the stiffness and mass matrices.

For static analysis the matrix equation is

$$\{F\} = [K]\{x\} \tag{11}$$

Expanding [K] into a 2 x 2 matrix

$$\begin{Bmatrix} F_1 \\ F_2 \end{Bmatrix} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} \tag{12}$$

$$F_1 = K_{11}x_1 + K_{12}x_2 \tag{13}$$

$$F_2 = K_{21}x_1 + K_{22}x_2 \tag{14}$$

Solving for x_2 in equation (14)

$$x_2 = K_{22}^{-1}(F_2 - K_{21}x_1) \tag{15}$$

Substituting this value of x_2 in equation (13)

$$K_{11}x_1 + K_{12}K_{22}^{-1}(F_2 - K_{21}x_1) = F \tag{16}$$

$$(K_{11} - K_{12}K_{22}^{-1}K_{21})x_1 = F_1 - K_{12}K_{22}^{-1}F_2 \tag{17}$$

or

$$[K]^*\{x_1\} = \{F^*\} \tag{18}$$

where $[K]^*$ and $\{F^*\}$ are modified stiffness matrix and force vector respectively

$$[K^*] = K_{11} - K_{12}K_{22}^{-1}K_{21} \tag{19}$$

The matrix manipulations, like decomposition or inversion, must be performed on such smaller matrices as K_{11}, K_{12}, or K_{22}. Because computation time is directly proportional to the square of the number of terms in the matrix, the Guyan reduction results in an efficient, economical solution. In the stiffness matrix reduction, equation (19), there is no approximation involved.

The mass matrix can also be reduced in a similar fashion, but some approximation is involved, the effect of which should be negligible in the final results. In dynamic analysis, the reduction technique depends upon retaining a small proportion of the unknown nodal deflections, called masters. The remaining deflections, known as slaves, are reduced out. Hence the order of the eigenvalue problem is reduced. With a careful choice of masters, the lower natural frequencies are preserved and can be accurately found.

The eigenvalue problem in matrix form is rewritten as

$$([K] - \omega^2 [M]) \{x\} = 0 \tag{20}$$

The matrices in partitioned form are

$$\left(\begin{bmatrix} K_{mm} & K_{ms} \\ \hdashline K_{sm} & K_{ss} \end{bmatrix} - \omega^2 \begin{bmatrix} M_{mm} & M_{ms} \\ \hdashline M_{sm} & M_{ss} \end{bmatrix} \right) \begin{Bmatrix} X_m \\ \hdashline X_s \end{Bmatrix} = \begin{Bmatrix} 0 \\ \hdashline 0 \end{Bmatrix} \tag{21}$$

X_m and X_s are master and slave degrees of freedom respectively.

In order to eliminate the slaves, it has been observed that, for low frequencies, the effects of inertia forces on the slave displacements are small compared with the effects of static forces. Therefore, the inertia forces arising due to the lower row of the mass matrix in the partitioned matrix, equation (21), are ignored. Expand equation (21) with this assumption

$$K_{mm}X_m + K_{ms}X_s - \omega^2 M_{mm}X_m - \omega^2 M_{ms}X_s = 0 \tag{22}$$

$$K_{sm}X_m + K_{ss}X_s = 0 \tag{23}$$

From equation (23)

$$X_s = -K_{ss}^{-1} K_{sm}X_m \tag{24}$$

Use equation (24)

$$\{x\} = \begin{Bmatrix} X_m \\ X_s \end{Bmatrix} = \begin{bmatrix} I \\ -K_{ss}^{-1} K_{sm} \end{bmatrix} \{X_m\} \tag{25}$$

The kinetic and strain energies in terms of master degrees of freedom system can be written as

$$\text{strain energy} = \tfrac{1}{2} \{X_m\}^T \; [K^*] \; \{X_m\} \tag{26}$$

$$\text{kinetic energy} = \tfrac{1}{2}\omega^2 \{X_m\}^T [M^*] \; \{X_m\} \tag{27}$$

where $[K^*]$ and $[M^*]$ are reduced stiffness and mass matrices respectively.

Strain energy and potential energy in terms of total degrees of freedom are

$$\text{strain energy} = \tfrac{1}{2} \{X\}^T \; [K] \; \{X\} \tag{28}$$

$$\text{Kinetic energy} = \tfrac{1}{2}\omega^2 \{X\}^T \; [M] \; \{X\} \tag{29}$$

Substituting equation (25) in equations (28) and (29)

$$[K^*] = K_{mm} - K_{sm}K_{ss}^{-1}K_{ms} \quad \text{and} \tag{30}$$

$$[M^*] = M_{mm} - K_{ss}^{-1} K_{sm}M_{sm} - M_{ms}K_{ss}^{-1} K_{sm} + K_{ss}^{-1} K_{sm}M_{ss}K_{ss}^{-1} K_{sm} \tag{31}$$

There is no approximation involved in equation (30).

But how to select the master degrees of freedom to obtain good accuracy? The criteria for the choice of an automatic master is based on the ratio of K_{ss} to M_{ss} terms. If one slave displacement is desired, the degree of freedom with the largest K_{ss} to M_{ss} ratio should be chosen. This is based on the assumption that mass terms corresponding to slave displacements have a negligible effect on mode shape. The method therefore involves scanning the leading diagonals of the [K] and [M] matrices to find the degrees of freedom that yield highest K_{ss} to M_{ss} ratios. The user then must decide only on the number of automatic masters required.

Substructuring is also useful in the building block approach, in which each component of a structure is separately analyzed and coupled at certain points. These connection points are the dynamic degrees of freedom or the master degrees of freedom. The components in the building block approach can be analyzed either analytically, using finite element techniques, or empirically. Experimental techniques have advanced in the past few years so that dynamic properties can be measured by exciting the structure by impact, or by random or swept sinusoidal loads.

The dynamic characteristics are determined through frequency response and mode shapes of the structure. The frequency response is obtained with a controlled excitation force; both force and response are measured. The response could either be displacement, velocity, or acceleration. Experimental frequency response techniques have reached such a sophisticated stage mainly because of the algorithm for rapid Fourier Transform, which is commonly known as Fast Fourier Transform, or FFT.

Experimental modal analysis is important when damping is predominant. The analytical finite element method with damping is complex, and such assumptions as proportional damping must be made to include the contributions due to damping. Such an assumption is in general not realistic except in lightly damped structures. For heavily damped structures, the exact modal contribution of damping might be important.

The finite element solution involves considerable clerical work to keep track of the joint co-ordinates and element connectivity. For a large problem checking the geometry of the model will cost more than the actual computer processing! Several graphic techniques are available now. Using these techniques model creation time is considerably improved. Digitizer tablets are available that create a model from a drawing, thereby reducing the burden on the analyst.

Graphic techniques are also available to animate the vibrating shapes of structures. Color coded graphics are also available to plot stresses and strain energy levels.

The finite element technique has been used for structural analysis, and in such other areas as lubrication, fiber industry, panel flutter, and biomechanics. The buckling of structures is also an eigenvalue problem and a technique analogous to that described here has been used. Current extension of the finite element method involves finding the stress intensity factor and notch factor for fatigue and fracture mechanics analyses. Thus the capability for a complete evaluation of the useful life of a product will soon be available at the drawing stage, given the typical dynamic environment of the product and a finite element dynamic analysis.

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LITERATURE REVIEW

survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains review articles on aeroacoustics and plate vibrations. Dr. Arndt, Director of the St. Anthony Falls Hydraulic Laboratory, has prepared an interesting sketch on aeroacoustics: jet noise and noise from rotating blades.

Dr. Leissa of Ohio State University has prepared a review of the literature on recent research in plate vibrations. Dr. Leissa is the author of the popular monographs on plate and shell vibrations.

A SKETCH OF AEROACOUSTICS

R.E.A. Arndt*

***Abstract** - This article reviews the state of the art in aeroacoustics. Aircraft noise sources are summarized. Two major noise sources -- jet noise and noise from rotating blades -- are described in detail. Research trends are mentioned.*

The general problems of noise reduction and acoustic fatigue fall within the general area of a new and challenging field called aeroacoustics -- an amalgam of aerodynamics and acoustics. Both are well developed disciplines; only in recent years has the aerodynamicist had much to do with acoustics and the acoustician with aerodynamics. The birth of aeroacoustics is often attributed to the classical publications of Lighthill [1] in 1952 and 1954. The theoretician would say that the propagation of low to medium intensity acoustical waves is but one example of a weakly perturbed compressible flow and that many features of high intensity acoustic waves or nonlinear acoustics are also known to the aerodynamicist. However, in practice, the acoustician is generally concerned with linear phenomena and with such properties of non-dispersive waves as transmission, reflection, refraction, and defraction. The aerodynamicist has been concerned mostly with such nonlinear phenomena as convective acceleration of fluid particles over bodies, vorticity, and turbulence in different types of flow fields. Classical acoustics is concerned with sound from such external forces as a loudspeaker, a vibrating violin or a blacksmith pounding an anvil with a hammer. Aeroacoustics is concerned with sound produced by the motion of fluids or bodies in the atmosphere and by such chemical processes as the combustion of jet fuel. Thus the intensity of sound from a given source is determined from aerodynamic considerations. The study of sound propagation is based on the principles of classical acoustics.

The discovery that the flow of a fluid or air over a body can create sound dates from the classical work of Strouhal [2] published in 1878. The foundations of propeller and helicopter rotor noise were laid down more recently. Gutin [3] demonstrated in the late 1940s that the steady blade loads (relative to the propeller) associated with a thrusting rotor can produce sound. At about the same time Yudin [4] provided a way to study the noise due to unsteady propeller blade forces associated with vortex shedding phenomena. The classic work of Lighthill [1] provided the first firm theoretical basis for the study of noise due to a flowing medium in the absence of boundaries. Lighthill's work follows traditional lines in that he lumped the aerodynamics of the problem into an equivalent acoustic source strength. Crow [5] published an attempt to provide an integrated theory of jet noise in 1970. He formulated the aerodynamic sound emission problem in terms of matched asymptotic expansions; the inner solution provided a physical description of a compressible vortical flow (turbulence), and the outer solution consisted of a weakly perturbed wave-like motion (the acoustic radiation). In my opinion this paper is the basis for a unified approach to aeroacoustics and perhaps indicates the direction in which the future of aeroacoustics could be structured.

There is a need to train people to work in aeroacoustics. Active work dates back only about 25 years, yet the field has a firm theoretical foundation. The major developments are associated with aircraft noise, but possibilities in other fields are almost limitless. It is the aim of this paper to review the state of the art in aeroacoustics.

AIRCRAFT NOISE SOURCES

A typical jet engine is shown in Figure 1. Several internal rotating devices -- fan, compressor, and turbine -- generate noise that propagates from the inlet and discharge ducts. The burning of fuel in the engine is also a noise source, as are the discharges of hot gases from the turbine and of cold air from the fan that provide the engine thrust. The identification of a noise source and the study of noise propagation are complex. Various noise sources can contribute to the total noise problem. As a jet aircraft approaches

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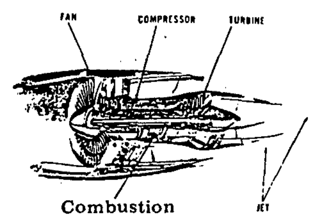

Figure 1. Jet Engine Noise Sources (After Sofrin)

an observer, the noise signature is dominated by noise propagating out the inlet (Fig. 2). As the aircraft passes overhead, the noise that has propa- ;ated out of the discharge ducts predominates; finally, as the aircraft leaves the observation point, the low frequency rumble of the jet exhaust dominates. Thus, many noise sources must be considered simultaneously in considering ways to decrease the overall noise level for a given aircraft.

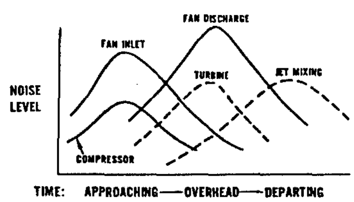

Figure 2. Flyover Noise History for a Jet Transport

Multiple noise sources are evident in Figure 3 which is a spectrum of noise from a typical helicopter. Both pure tone noise and broadband noise are present, and such components as the main rotor, tail rotor, power plant, and gearbox contribute to the noise signature.

Jet Noise

One major aircraft noise source is the fluctuating pressure field generated by the mixing of a high velocity jet with the atmosphere. Jet noise studies focus on the precise nature of the turbulence created by the mixing process, the exact nature of the sound generating mechanism -- including whether or not the major source involves the formation of a turbulent eddy or its decay -- whether or not some orderly structure in a turbulent jet tends to enhance the acoustic efficiency of turbulent noise sources, and the sound due to the interaction of turbulence

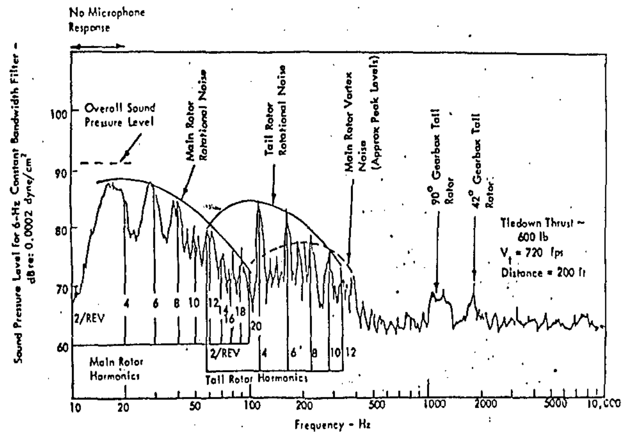

Figure 3. UH-1A External Noise Spectrum

and the shock structure in a turbulent jet. Jet suppressor technology has not yet been developed to the point that a rational approach to jet noise suppression is possible.

Much of what is known about jet noise has been deduced from a few basic principles that are briefly reviewed below. The Lighthill acoustic analogy was developed from the conservation of mass and momentum in a general fluid flow.

$$\frac{\partial^2 \rho}{\partial t^2} - a_o^2 \frac{\partial^2 \rho}{\partial x_i \partial x_i} = \frac{\partial^2 T_{ij}}{\partial x_i \partial x_j} \qquad (1)$$

$$T_{ij} \cong \rho_o u_i u_j \qquad (2)$$

In the equations ρ is the density, and a_o the acoustic velocity in the undisturbed medium. A formal solution to equation (1) is given by

$$p' = \frac{1}{4\pi a_o^2} \frac{x_i x_j}{|\underset{\sim}{x}|^3} \int_{\nabla} \frac{\partial^2 T_{ij}}{\partial t^2} [\underset{\sim}{y}, t'] \, dy \qquad (3)$$

$$t' = t - \frac{r}{a_o}, \quad r = |\underset{\sim}{x}| \qquad (4)$$

In equation (3) p' is the pressure level at $\underset{\sim}{x}$ due to a distribution of sound sources in the volume ∇, and the position of each sound source is $\underset{\sim}{y}$. Although the actual solution of equation (3) requires extensive measurement of the turbulent velocity field, Lighthill and others have suggested that many of the general features of jet noise can be inferred from similarity principles.

Assume that the total sound at a given point is made up of the contribution of many uncorrelated sound sources within the jet. The sound from a volume of turbulence is then given by equation (5).

$$p' \cong \frac{x_i x_j V_e}{4\pi a_o^2 |\underset{\sim}{x}|^3} \ddot{T}_{ij} (t - \frac{r}{a_o}) \tag{5}$$

V_e is the volume over which a given sound source is correlated. The intensity I and total radiated power W are related to the square of the acoustic pressure.

$$I \equiv \frac{\overline{p'^2}}{\rho_o a_o} \tag{6}$$

$$W \sim I |\underset{\sim}{x}|^2 \tag{7}$$

The total power radiated per unit volume of turbulence is therefore given by

$$\frac{W}{Vol} = \frac{V_e \omega^4 T_{ij}^2}{\rho_o a_o^5} \tag{8}$$

Equation (8) assumes that differentiation with respect to time is proportional to a characteristic frequency ω. The variation of radiated acoustic power, the sound power per unit slice of jet, and the spectral characteristics of jet noise can be estimated from equation (8).

Detailed information is needed on the flow structure of turbulent jets; e.g., estimates for T_{ij} and V_e imply the need for turbulence measurements. In addition, two-point correlations are needed to estimate V_e, which can be said to be proportional to the cube of the integral scale. Figure 4 shows that a jet contains several different regions of flow. As the flow leaves the nozzle, a region of intense turbulent mixing is formed. The interchange in momentum between the core and the mixing regions decreases the core region. At about four diameters from the nozzle the potential core ceases to exist; further mixing shifts the region of maximum turbulence intensity toward the centerline. In the fully developed region the profiles of mean and fluctuating velocities are similar; the profiles attain a maximum at the jet centerline.

Figure 5 shows the results of correlation studies with a hot wire anemometer in the mixing zone of a jet. The data are plotted in terms of contours of constant

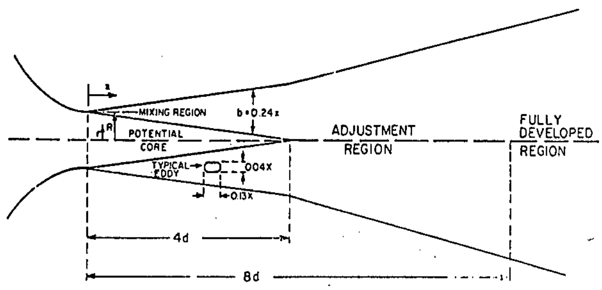

Figure 4. Flow Structure of Turbulent Jet

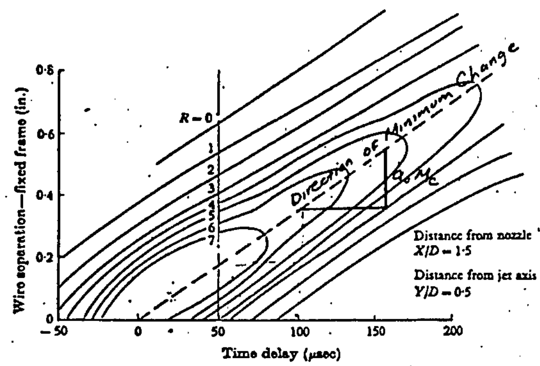

Figure 5. Correlation Studies in a Turbulent Jet [6]

correlation. A minimum change in correlation occurs in a certain direction in the space-time plane. The slope of this line is the convective speed of the eddies or acoustic sources in a jet because an observer moving with this speed sees the true time rate of change of the turbulent structure. It has been shown [6] that an autocorrelation in this frame of reference can be approximated by

$$R_\tau \sim \exp\left[-\frac{\tau}{T}\right] \tag{9}$$

$$T \cong \frac{4.5}{\frac{\partial \bar{u}}{\partial r}} \tag{10}$$

The turbulence intensity in the region is proportional to the mean shear $\frac{\partial \bar{u}}{\partial r}$ and the scale of the turbulence L.

$$u' \cong 0.2 \frac{\partial \bar{u}}{\partial r} L \tag{11}$$

Furthermore, the product of Tu′ is proportional to the scale of the turbulence.

$$Tu' \cong 0.9L \tag{12}$$

Thus the characteristic frequency ω in equation (8) is given by

$$\omega \sim \frac{1}{T} = 1.1 \frac{u'}{L} \tag{13}$$

and in the mixing region

$$\frac{2\pi\omega d}{U_j} = 0.53 \left(\frac{x}{d}\right)^{-1} \tag{14}$$

A summary of measured and estimated turbulence data and the acoustic properties that can be inferred from these data is presented in Table 1. The estimates of acoustic properties are based on equation (8) and the following assumptions. The effective volume is assumed proportional to the cube of the eddy scale.

$$V_e \sim L^3 \tag{15}$$

Similarly the source strength T_{ij} is given by

$$T_{ij} \sim \rho_o u'^2 \tag{16}$$

The sound power per unit slice of jet is estimated from

$$\frac{dW}{dx} \cong \frac{W}{Vol} \frac{Vol}{Slice} \tag{17}$$

where

$$\frac{Vol}{Slice} \sim d^2 \left(\frac{x}{d}\right) \quad \text{mixing region} \tag{18}$$

$$\sim d^2 \left(\frac{x}{d}\right)^2 \quad \text{fully developed} \tag{19}$$

In the adjustment region the estimate is

$$\frac{Vol}{Slice} \sim d^2 \left(\frac{x}{d}\right)^{3/2} \tag{20}$$

Table 1. Measured Functional Properties of Jet Turbulence and Inferred Acoustic Characteristics

Flow Property/Region	Mixing	Adjustment (estimated)	Fully Developed
$\frac{u'}{U_j}$	const	$\left(\frac{x}{d}\right)^{-1/2}$	$\left(\frac{x}{d}\right)^{-1}$
$\frac{L}{d}$	$\frac{x}{d}$	$\left(\frac{x}{d}\right)^{1/2}$	$\frac{x}{d}$
$\frac{a_o^5 d}{\rho_o U_j^8} \frac{W}{Vol}$	$\left(\frac{x}{d}\right)^{-1}$	$\left(\frac{x}{d}\right)^{-2/3}$	$\left(\frac{x}{d}\right)^{-9}$
$\frac{a_o^5}{\rho_o U_j^8 d} \frac{dW}{dx}$	const	$\left(\frac{x}{d}\right)^{-3}$	$\left(\frac{x}{d}\right)^{-7}$
$\frac{a_o^5}{\rho_o U_j^8 d^2} S$	$\sim\left(\frac{\omega d}{U_j}\right)^{-2}$	$\frac{\omega d}{U_j}$	$\left(\frac{\omega d}{U_j}\right)^2$

Similarly the spectrum of the acoustic signal is estimated from

$$S(\omega) \equiv \left|\frac{dW}{d\omega}\right| \tag{21}$$

and

$$\frac{dW}{d\omega} = \frac{dW}{dx}\,\frac{1}{\dfrac{d\omega}{dx}} \tag{22}$$

The total radiated power of a jet is given by

$$W = \int_{o}^{\infty} \frac{dW}{dx}\,dx \tag{23}$$

which is

$$W \sim \frac{\rho_o U_j^{8} d^2}{a_o^{5}} \tag{24}$$

From a design point of view equation (24) is probably the most significant result of the jet noise theory. The inherent advantages of the fan jet engine are apparent from this equation: significant noise reduction is possible at a given thrust level by moving larger quantities of air at a lower jet velocity. Propulsive efficiency is also increased.

Solutions of equation (24) are compared with data measured for several variables in Figure 6. The agreement is remarkable. The trend of noise spectra is compared with experimental results in Figure 7; the expected results are again remarkably reliable.

From equation (24) it can be shown that acoustic efficiency varies with the Mach number to the fifth power. There is a limit, however to acoustic efficiency. The intensity of acoustic radiation is altered by the effects of convection.

$$I \sim \frac{\rho_o U_j^{8}}{a_o^{5} r^2}\,\frac{1}{c^5} \tag{25}$$

C is a convection factor

$$C = \left\{ (1 - M_c \cos\theta)^2 + \frac{\omega^2 L^2}{\pi a_o^{2}} \right\}^{1/2} \tag{26}$$

Convection Effect (Frozen Turbulence)

Eddy Decay

As the eddy approaches supersonic speed, Mach waves form at an angle to the flow direction.

$$\theta_c = \cos^{-1}\frac{1}{M_c} \qquad M_c > 1 \tag{27}$$

M_c is the convection Mach number. The implication of equation (27) is that very intense sound is focused at an angle θ_c to the jet. According to classical theory the sound would be very intense if the eddy were not decaying. Hence, when the eddies are convected supersonically, the convection factor C is not zero at θ_c but rather

$$C \cong \frac{\omega L}{a_o}, \; \theta = \cos^{-1}\frac{1}{M_c} \tag{28}$$

The acoustic intensity is thus

$$I \sim \frac{\rho_o U_j^{8}}{a_o^{5} r^2}\,\frac{1}{\left(\dfrac{\omega L}{a_o}\right)^5} \tag{29}$$

Because $\omega L \sim U_j$, the intensity is

$$I \sim \frac{\rho_o U_j^{3}}{r^2} \tag{30}$$

Equation (30) implies that acoustic efficiency is independent of Mach number. This result is in close agreement with observations of rocket noise.

Noise From Rotating Blades

One of the most common ways to impart or extract energy from a moving fluid is by aerodynamic lift in a rotating device. The most common devices in aerospace are propellers, helicopter rotors, fans, compressors, and turbines; all are important noise sources (see Table 2).

According to the theory of noise generation, the two fundamental types of noise sources are a dipole due to aerodynamic loading and a monopole due to the displacement that occurs when a blade of finite thickness is moving through the air. Turbulence created by the movement of the blades is an additional noise source. The major noise source common to all rotating devices, blade loading, is shown systematically in Figure 8. The relationship of the pressure field at $\underset{\sim}{x}$, due to a dipole at y moving relative to the observer with velocity $a_o M_r$, is

$$P' = \frac{x_i - y_i}{4\pi a_o r^2 (1 - M_r)^2} \left\{ \frac{\partial [F_i]}{\partial t} + \frac{[F_i]}{1 - M_r}\,\frac{\partial M_r}{\partial t} \right\} \tag{31}$$

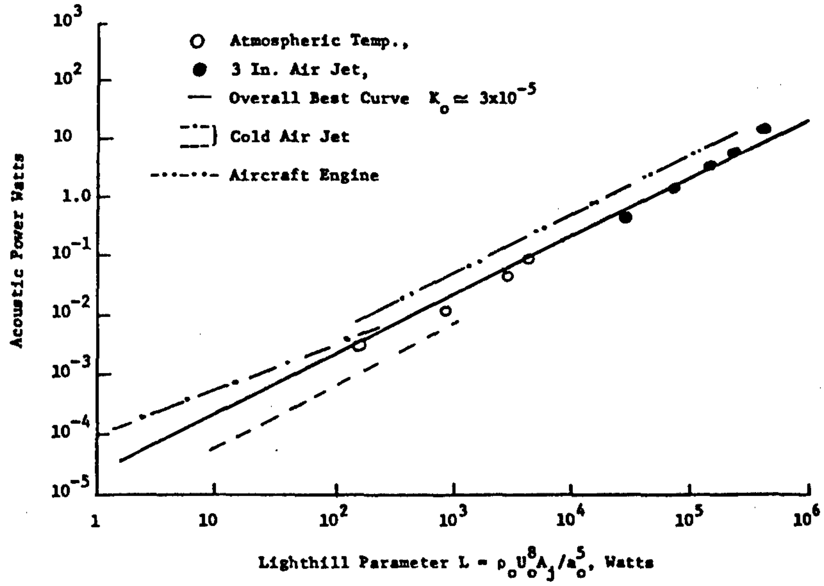

Figure 6. Acoustic Power as a Function of Lighthill Parameter

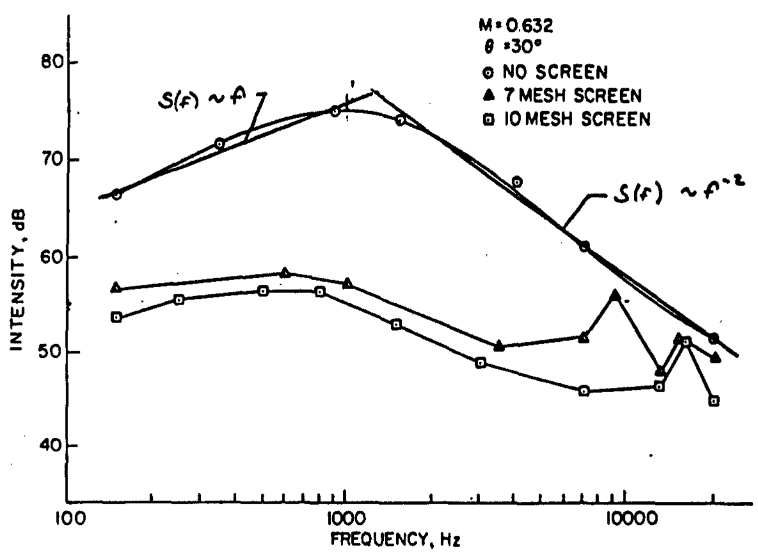

Figure 7. Frequency Spectrum of Jet Noise

Table 2. Typical Rotating Devices and Their Operating Conditions

Component	B	Chord Length (ft)	D(ft)	Tip Speed (ft/sec)	HP
Propellers	**2-6**	**0.3-1**	**5-12**	**500-1000**	**50-5,000**
Helicopter Rotors	**2-6**	**0.3-2**	**5-70**	**500-900**	**50-10,000**
Fans, Compressors Turbines	**15-80**	**0.05-0.5**	**0.5-9**	**500-2000**	**50-50,000**
Space System Impellers	**2-10**	**0.02-0.05**	**0.05**	**200-400**	**0.1-1**

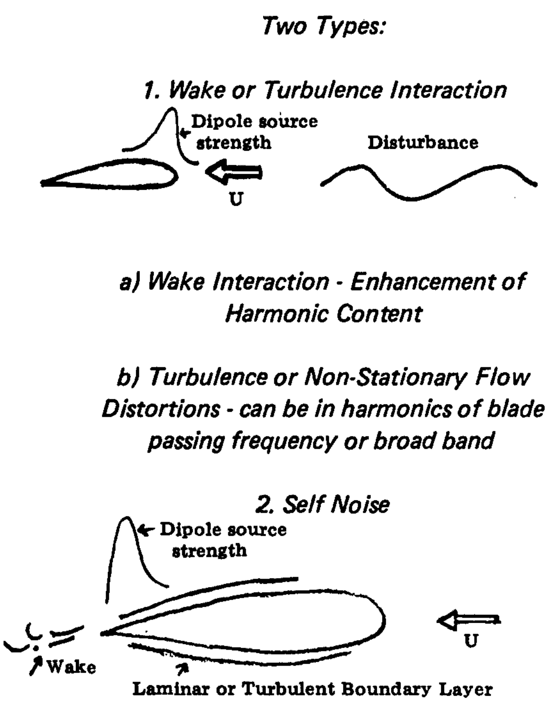

Figure 8. Schematic of Rotor Noise Blade Loading

Two contributors to the noise field are unsteady loads on the blade and acceleration of a steady load. Hence, if a propeller is operating with steady velocity in completely quiescent air, the blade load is steady and the first term in the brackets in equation (31) is zero. Only the steady load contributes to the sound field and is completely dependent on the centrifugal acceleration. Consideration of this case resulted in the classical equation relating the noise level in each blade passing harmonic mB to the number of blades B, the thrust T, and the torque Q [3].

$$\langle SP_{mB}\rangle = \frac{mBN}{\sqrt{2}Ra_o}\left[T\cos\delta - \frac{Q}{r_e M_e}\right] J_{mB}(mBM_e\cos\delta) \qquad (32)$$

$$M_e = \frac{2\pi N r_e}{a_o} \qquad (33)$$

N is the rotational speed, and δ is the angle the observer makes with the thrust line. Equation (32) is useful in design for determining the relative effects of blade loading, the number of blades, and the rotational speed on the noise signature. All harmonics of pressure are due to a pressure field that rotates at the basic rotor speed N. Unsteadiness has a significant effect. For example, if a flow distortion results in an unsteady blade loading at a specific blade position, the pressure level is considerably enhanced in the higher harmonics ($mB>1$). The problem is further complicated by the fact that the pressure level in each harmonic is made up of an infinite number of modes rotating with speeds

$$\omega_m = \frac{2\pi mBN}{mB \pm s} \qquad (34)$$

Here s corresponds to the harmonic of blade loading

$$L = L_o + \sum_{s=1}^{\infty} L_s\cos(s\psi - \theta_s) \qquad (35)$$

L is the lift on each blade, and ψ is the blade position. A typical example of this type of loading is the effect of forward flight on a helicopter rotor; the velocity relative to the advancing blade is higher than that relative to the retreating blade. Another example is a compressor in which the rotor blades repeatedly slice through the wakes of the upstream stator vanes. The effects of such flow unsteadiness are shown in Figure 9.

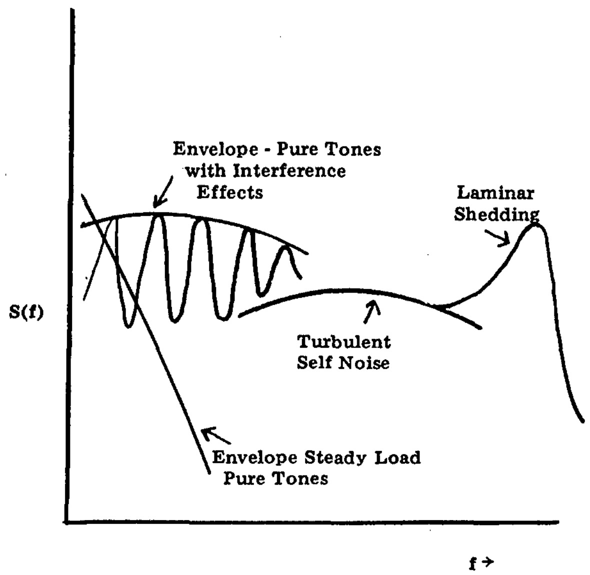

Figure 9. Schematic of Rotor Noise Spectrum

Changes in rotating modes are important when a rotor is placed in a duct -- the situation in a jet engine. According to theory a rotating pressure field propagates only in a thin annular duct of radius r_o if the rotational Mach number is greater than unity.

$$\frac{2\pi N r_o}{a_o} > 1 \tag{36}$$

Thus, no noise propagates from a rotor rotating with subsonic tip speed in a circular duct if no flow distortion is occurring. If a rotor with B blades is operating behind a stator with V blades, an infinite number of rotational modes exist in each harmonic mB. Each mode rotates with a speed given by equation (34); in this case s is kV, k being any integer.

$$\omega_{\pm k} = \frac{2\pi m B N}{mB \pm kV} \tag{37}$$

The noise level in any harmonic is thus critically dependent on the number of stator and rotor vanes. The worst situation is a device with an equal number of rotor and stator vanes because, regardless of the tip speed, each harmonic of a blade passing frequency will propagate. As shown by equation (37), an integer k always exists that makes ω infinite. This very important point has resulted in the removal of the fan inlet guide vanes in the newest jet engines.

TRENDS

This review of jet and fan noise has described some of the factors that control the acoustic output from various aircraft components. It should be pointed out that most of the dramatic advances in aircraft noise control thus far have been based on a few relatively simple facts that have emerged from a considerable research effort.

However, as is true of any aspect of noise control, as one noise source is diminished, another becomes prominent. Efforts are being made to understand combustion noise; the propagation of internal noise sources through complex ducts, rotors, and guide vanes; the effect of rotation on the decay of rotor and stator wakes so that spacing for noise control can be optimal; and the noise due to turbulence ingestion either in the boundary layer along the wall of the inlet duct or in the atmosphere. Considerable effort is being expended to clarify the performance of acoustic liners in the presence of flow. The liner itself is a source of flow noise, and recent investigations have shown that the acoustic impedance of the liner is affected by the structure of the flow over the liner.

It should be mentioned that even if jet engine noise were completely masked, a typical jet transport would still be extremely noisy. Figure 10 shows that airframe noise is significant. If further improvements in jet engine noise control technology become a reality, airframe noise will become a significant problem, especially if noise control regulations are made more strict. A myriad of aeroacoustic noise sources are associated with airframe noise -- boundary layer noise, interaction of boundary layer turbulence with the trailing edges of wings and control surfaces, interaction of acoustic modes and shear layer instabilities at cut-outs such as wheel wells, and vortex shedding noise.

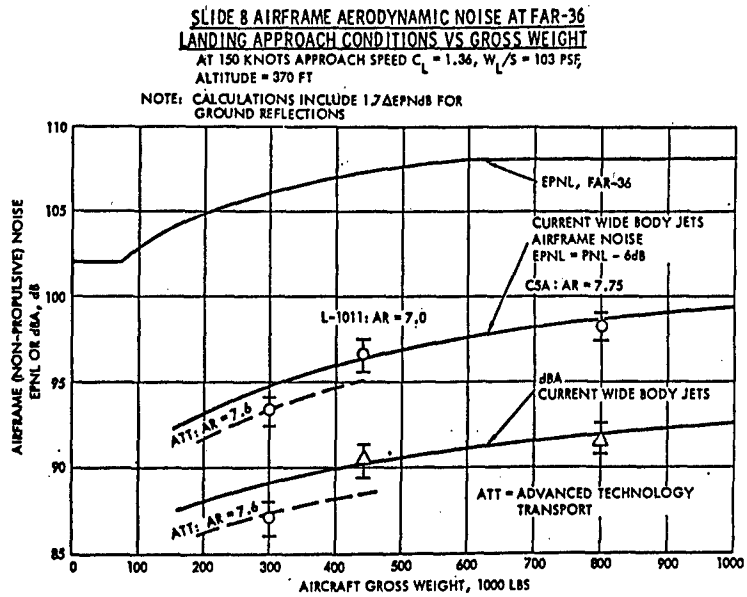

Figure 10. Predicted Airframe Noise

In addition, STOL and VTOL vehicles have special noise sources; e.g., blown flaps and jet flaps. It is of interest that these aeroacoustic problems touch on many areas in basic fluid mechanics as well as acoustics. For example, many recently published basic turbulence research results began as aeroacoustic problems.

Thus, although significant advances have been made in aircraft noise control, much remains to be done in the way of fundamental research, design, development of test facilities, development of sophisticated data processing techniques, and even in optimizing flight operational procedures for minimizing noise while maintaining a high degree of safety and performance.

ACKNOWLEDGMENTS

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RECENT RESEARCH IN PLATE VIBRATIONS. 1973 - 1976: COMPLICATING EFFECTS

A.W. Leissa*

This paper is a review of literature dealing with the complicating effects of free, undamped vibrations of plates that appeared from 1973-1975 and in part of 1976. Recent research dealing with the complicating effects of anisotropy, in-plane forces, variable thickness, surrounding media, large deflections, shear deformation, rotary inertia, and nonhomogeneity (including layered plates) is summarized.

A previous paper [1] reviewed the recent literature of free vibrations of plates according to classical theory. Classical theory is governed by the equation of motion

$$D\nabla^4 w + \rho \frac{\partial^2 w}{\partial t^2} = 0 \tag{1}$$

That survey dealt with literature published from the beginning of 1973 through part of 1976; the present paper continues the survey and includes eight complicating effects, each of which requires generalization of equation (1) and increases the difficulty in obtaining analytical solutions for free vibration frequencies, nodal patterns, and mode shapes.

ANISOTROPIC PLATES

For plates having general anisotropy the term $D\nabla^4 w$ in equation (1) must be greatly expanded. Isotropic materials that have only two independent elastic coefficients -- usually taken as E (Young's modulus) and ν (Poisson's ratio) -- can be combined into a single flexural rigidity parameter, D. Definition of a generally anisotropic plate requires five independent rigidity parameters. Because of the number of additional parameters and terms required in equation (1), as well as further complications owing to coupling between derivatives, no results for the vibration of generally anisotropic plates are known to the author.

Orthotropic plates require the definition of three independent rigidity parameters. Thus, thorough numerical studies require the variation of two parameters that are ratios of flexural rigidities. Furthermore, orthotropy can be defined with respect to various coordinate systems: the two most commonly used are polar and rectangular. Some recent work has also been done with skew orthotropy.

Polar Orthotropy

In the case of polar orthotropy equation (1) generalizes to

$$D_r \frac{\partial^4 w}{\partial r^4} + 2\frac{D_{r\theta}}{r^2}\frac{\partial^4 w}{\partial r^2 \partial \theta^2} + \frac{D_\theta}{r^4}\frac{\partial^4 w}{\partial \theta^4} + 2\frac{D_r}{r}\frac{\partial^3 w}{\partial r^3}$$
$$-2\frac{D_{r\theta}}{r^3}\frac{\partial^3 w}{\partial r \partial \theta^2} - \frac{D_\theta}{r^2}\frac{\partial^2 w}{\partial r^2} + \frac{2}{r^4}(D_\theta + D_{r\theta})\frac{\partial^2 w}{\partial \theta^2}$$
$$+\frac{D_\theta}{r^3}\frac{\partial w}{\partial r} + \rho\frac{\partial^2 w}{\partial t^2} = 0 \tag{2}$$

D_r, D_θ, and $D_{r\theta}$ are the appropriate flexural rigidity parameters [2]. Equation (2) permits separation of variables.

Axisymmetric vibrations of clamped circular plates have been analyzed [3]. Particular attention was given to the questionable meaning of polar orthotropy at the origin (r=0).

Ramaiah and Kumar [4, 5] made a thorough study of annular plates. The Ritz method was used with algebraic polynomial deflection functions [4] to obtain frequency parameters for all nine combinations of simple boundary conditions for various ratios of flexural rigidities and of boundary radii (b/a). Simple approximate formulas expressed the orthotropic frequencies in terms of flexural rigidity ratios and the frequencies of corresponding modes in the axisymmetric case. A simplified method based upon the assumption that the radial bending moment is small at a nodal circle [5] was shown to be especially useful for estimating frequencies of modes having a large number of nodal circles.

Orthotropic circular plates having concentric iso-

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tropic cores have been analyzed [6, 7]. Axisymmetric frequencies were given for cases having clamped and simply supported boundaries. Annular corrugated disks have been represented by orthotropic plates [8] for the theoretical analysis of the case in which the outside boundary is free and the inside one clamped; theoretical results were compared with experimental ones.

Rubin [9] used the Frobenius method to study annular sector plates with radial edges simply supported. Numerical results were presented for a case with the inner boundary clamped and the outer one free. Vibrations of circular polar orthotropic plates have also been studied [10-13].

Rectangular Orthotropy

For rectangular orthotropy equation (1) becomes

$$D_x \frac{\partial^4 w}{\partial x^4} + 2D_{xy} \frac{\partial^4 w}{\partial x^2 \partial y^2} + D_y \frac{\partial^4 w}{\partial y^4} + \rho \frac{\partial^4 w}{\partial t^2} = 0 \quad (3)$$

D_x, D_y, and D_{xy} are the appropriate flexural rigidity parameters [2].

The six cases of rectangular plates having two opposite edges simply supported have straightforward, exact solutions [2]. This procedure has been used [14-18] as a basis for comparison of approximate methods. Aksu and Ali [15] demonstrated a finite difference method using an unequal interval formulation; an optimum interval variation parameter was determined. Vijakumar [16] applied Bolotin's asymptotic method to obtain numerical results for five of the six cases. A finite-strip-difference technique was utilized and discussed [17, 18].

The rectangular orthotropic plate clamped on all edges has been studied [19-22]. Bauer and Reiss [19] used the perturbation method; the isotropic solution supplied the leading term in the perturbation expansion. King and Lin [22] used Bolotin's method to obtain results for the CFCF plate as well.

For plates of other shapes with rectangular orthotropy, an interesting reduction method has been demonstrated [23]. A frequency of one plate was estimated from that of another having a different shape. The method was demonstrated for the clamped ellipse (derived from results for the circle) and for the simply supported skew (parallelogram) plate (derived from the simply supported isotropic rectangular plate).

Maurizi and Laura [24] investigated rectangular plates having rectangular axes of orthotropy rotated through an angle ϕ with respect to the plate edges. The Galerkin method with algebraic polynomials was used to derive formulas for the first four frequencies of a clamped rectangular plate. Curves were plotted for an example representing a unidirectional boron-epoxy material.

Srinivasan and Munaswamy [25] studied the problem of the parallelogram plate having four free edges and supported at four interior points. The problem was solved by means of skew finite strips; extensive numerical results showing frequency parameters and mode shapes were presented [25].

Orthotropic parallelogram plates have also been treated [26], as have trapezoids [27]. Other references deal with free vibration of plates having rectangular orthotropy [28-30].

Skew Orthotropy

The case of a material with principal axes of orthotropy that are straight but not orthogonal has been investigated by Nair and Durvasula [31]. They used the Ritz method and presented extensive numerical results for square and skew plates having various combinations of boundary conditions. Orthotropic rhombic plates have also been studied [32].

IN-PLANE FORCES

The presence of in-plane forces during the vibration of a plate requires additional terms in equation (2); they are second derivatives of w. If the in-plane forces are constant with respect to the space variables, the additional terms will have constant coefficients. For example, one important case is that of hydrostatic normal stress – i.e., constant normal stress in all directions -- for which equation (1) becomes

$$D\nabla^4 w - N\nabla^2 w + \rho \frac{\partial^2 w}{\partial t^2} = 0 \quad (4)$$

N is the constant tensile in-plane force per unit length of boundary. Generally speaking, tensile in-plane forces increase the vibration frequencies, whereas compressive forces decrease them. Reduction of a frequency to zero yields a buckling load for the plate.

Circular Plates

Considerable recent research on the circular plate subjected to hydrostatic loading and supported elastically on the boundary has been done [33-37]. Both translational and rotational edge springs were considered [36]. A concentrated mass was added at the center [37]. Extensive results were presented [34].

The rotation about the polar axis as a cause of variable in-plane stresses, as well as thermal in-plane stresses, have been studied [38, 39]. Nieh and Note [38] compared experimental results with theoretical ones.

Some recent work has dealt with the annular plate [40-43]. Rosen and Libai [40, 41] studied the case in which the outer edge is simply supported and uniformly compressed, and the inner one is free. Simple one-term Rayleigh solutions were derived for the vibration modes having no internal nodal circles. Numerical results were compared with experimental ones. Loh [42] treated the case when the inner edge is simply supported and uniformly compressed, and the outer one is either simply supported or free and is free of in-plane loads. The disk is simultaneously spinning about its polar axis. The rotating disk has been studied [43, 44].

Rectangular Plates

It can be shown [2] that in rectangular coordinates the effects of in-plane forces are accounted for by adding the terms

$$N_x \frac{\partial^2 w}{\partial x^2} + 2\, N_{xy} \frac{\partial^2 w}{\partial x \partial y} + N_y \frac{\partial^2 w}{\partial y^2} \tag{5}$$

to the right-hand sides of equations (1) or (3), where the N's are the positive in-plane normal and shearing forces per unit length (either constant or variable). For the special case of hydrostatic loading equation (4) results.

For N_x and N_y constant, and $N_{xy} = 0$, the six cases of rectangular plates having two opposite edges simply supported have straightforward, exact solutions [2]. Cases of this type have been studied [14, 45, 46].

Dickinson [47] analyzed the orthotropic, clamped, square plate subjected to hydrostatic loading by means of Bolotin's method. Plates having two parallel edges clamped and the other two free have been discussed [48]. The effects of residual stresses upon frequencies of a free plate with a weld longitudinally along its center have been examined [49]. Extensive numerical results for simply supported plates having different rotational springs along various edges and subjected to biaxial in-plane loads (N_x and N_y) have been obtained by Laura and Romanelli [50]. Other references deal with rectangular planes having in-plane loads [51-53].

Other Shapes

Jones and Mazumdar [54] addressed the problem of the hydrostatically loaded, elliptical plate having clamped or simply supported edges. Numerical results were given for a wide range of loading parameters and for various aspect ratios. Natural frequencies of plates having elliptical holes have been studied [55]. Analytical results from the Galerkin method were compared with experimental ones. Rhombic (parallelogram) and trapezoidal plates have been treated, [32] and [27] respectively.

PLATES WITH VARIABLE THICKNESS

For plates having variable thickness the flexural rigidity (D) is no longer constant, and several terms containing variable coefficients must be added to equation (1) [2].

Circular Plates

Solid circular plates have been discussed [43, 56-59]. Kirkhope and Wilson [43] used annular finite elements to analyze free plates with parabolic thickness variation. They obtained extensive results for modes having 0 to 6 nodal diameters and 0 to 3 nodal circles. Polar orthotropic disks having exponential thickness variation were examined by Ghosh [56]. The axisymmetric modes of plates having linear and parabolic thickness variation have also been analyzed [57], as have plates with a single step in thickness [58].

Annular circular plates with linear thickness variations have been considered [60-63]. Ramaiah and Vijayakumar [60] made a thorough study for thickness variations, both increasing and decreasing with the radius; all nine possible combinations of simple edge conditions; various taper ratios and boundary radii ratios; and 0 to 2 nodal diameters. They used the Ritz method with nine trial functions in the radial direction, which should be sufficient to give accurate results. Soni and Amba-Rao [61, 62] examined the axisymmetric modes of plates having the inner edge clamped, the outer edge being clamped, simply supported, or free. The finite element method was used [63] to obtain the first two frequencies for the nine combinations of edge conditions except free-free.

The effects of in-plane forces acting on tapered circular plates have been investigated [39, 64].

Rectangular Plates

Rectangular plates having linear thickness variation along one of the directions parallel to an edge have been considered [65-72]. Eastep [65] used the perturbation method on the simply supported square plate. Simply supported orthotropic plates were studied by Sakata [66] for various taper ratios, aspect ratios, and ratios of orthotropic constants. Plates having two opposite sides simply supported and the other two either simply supported or clamped and subjected to thermal gradients were examined by Rao and Satyanarayana [67].

Other thickness variations have been considered [71-76]. Rectangular plates having the sides $y = 0$, b simply supported, and parabolic thickness variation in the x-direction have been studied [71]. The infinite strip of parabolic thickness variation in the transverse direction and its edges simply supported and/or clamped was treated by Tomar and Gupta [73]. Soni and Rao [74] analyzed plates having $y = 0$, b simply supported, $x = 0$ clamped, and $x = a$ clamped, simply supported or free, with exponential thickness variation in the x direction, for various taper ratios and aspect ratios. Wertz [72] used the perturbation method to investigate square, simply supported plates having linear thickness variation in two directions simultaneously (maximum or minimum thickness at center) and compared the results with finite difference, finite element, and experimental results. He also treated one case involving stepped thickness. Olhoff [75] considered the problem of determining the plate thickness variation that maximizes the fundamental frequency for a given volume. The finite difference method was used on the resulting nonlinear partial differential equations.

Other Shapes

Chopra and Durvasula [77] addressed the problem of the rhombic plate with linearly varying thickness using the Ritz method with beam functions. Numerical results were obtained for the case when the opposite sides are simply supported and the other two are clamped and for various skew angles and taper ratios. Dokainish and Kumar [26] considered the completely clamped parallelogram having linearly varying thickness and orthotropic elastic constants in terms of orthogonal axes. The first two frequencies were found for various values of aspect ratio, skew angle, and taper ratio. Other results for the clamped parallelogram plate having linear thickness variation are also available [78]. Bailey and Greetham [27] examined trapezoidal plates having variable thickness with the additional complicating effects of thermal stress and orthotropy.

THE EFFECTS OF SURROUNDING MEDIA

Analytical solutions of free vibration problems are almost always based upon the assumption that the vibrating body is in a vacuum. Real problems and experimental simulations usually take place in air. Some references [2] have been made that deal with this difference, which can be significant. However, apparently no recent research has been done on this topic.

LARGE DEFLECTIONS

The term large deflections here refers to transverse deflections sufficiently large to cause additional stiffening of the plate due to membrane stretching at the midplane. This effect is usually significant for maximum deflections on the order of the plate thickness or more, and depends considerably on edge conditions. The simple governing equation of motion must be replaced by two coupled, nonlinear differential equations that include the effects of membrane stretching. A hypothesis due to Berger [79] simplifies the equations somewhat and is often used. Much recent research has been done for large deflection vibrations of plates; brief descriptions are given below.

Circular Plates

Solid circular plates have been treated [80-88], including clamped [80-84], simply supported [80-83], elastically supported [85], and discontinuous [86, 87] boundary conditions. In addition, the effects of an elastic foundation [81] and of polar orthotropic material [82, 83, 87] have been studied. Notable for its good bibliography, especially from other countries, is the work of Sathymoorthy and Pandalai [88]. Vendham [84] made an interesting critical study of the Berger equations and compared them with the von Kármán equations; he found that the former do not give consistently accurate results and may even yield different mode shapes.

Annular plates have been considered [88-92]. Sandman and Walker [89] presented experimental results. Huang [90] included a concentric isotropic core. In one case [91] the annulus having its inner boundary clamped and outer free was considered for constant thickness and for thickness partly constant and partly linearly tapered.

Rectangular Plates

Large amplitude oscillations of rectangular plates have been widely studied [68, 81, 83, 88, 93-105]. Simply supported [81, 84, 93-97], clamped [81, 84, 93-95], and other plates having combinations of boundary conditions [68, 95, 98] have been investigated; it must be remembered that the in-plane, as well as transverse, edge constraint conditions must be defined in each problem. In addition, elastic edge constraints [99, 100], discontinuous edge conditions [101] -- square plates having portions of their boundaries clamped, other portions simply supported -- a concentrated mass [102], an elastic foundation [81, 103], orthotropic material [94, 104], and variable thickness [68] have been studied. Ramachandran and Reddy [68] were able to establish bounds on the nonlinear fundamental frequency.

Other Shapes

Parallelogram plates have been analyzed [78, 88, 106-108] for various edge conditions, including the effects of orthotropy [78, 107] and variable thickness [78]. Various shapes of triangular plates were also examined [84, 88, 93, 109, 110], including the effects of orthotropy [110] and an elastic foundation [81, 109]. Elliptic plates have also been studied [88]. Datta [81] presented an interesting method using conformal mapping, along with the Galerkin procedure, which can accommodate a wide variety of shapes.

Other references deal with large amplitude vibrations of plates [111-115].

SHEAR DEFORMATION AND ROTARY INERTIA

For relatively thick plates ($h/l > 1/20$, where h is the plate thickness and l is an average length in its plane) the effects of shear deformation and rotary inertia become significant. The inclusion of shear deformation in the analysis of plate vibrations requires considerable generalization of equation (1). It is replaced by a sixth order set of equations; the most widely used in dynamic problems is that derived by Mindlin [116]. For this sixth order theory, three boundary conditions must be specified along an edge.

Circular Plates

The vibrations of thick, solid, circular plates have been studied [117-121]. Chandrasekaran and Kunukkasseril [117] obtained results for the first 20 modes for four types of clamped and supported edge conditions. They compared the results of classical and sixth order theories. Isotropic plates having clamped or supported edges have also been investigated [118, 119]. The effects of orthotropy have been included [120, 121]. Soni and Amba-Rao [120] presented numerical results for the first five axisymmetric modes of an orthotropic plate having linear thickness variation.

Thick, annular plates have been considered [122, 123]. Rao and Prasad [122] reported extensive numerical results for the nine combinations of usual boundary conditions (clamped, simply supported, or free) for inner and outer circular boundaries. Results were reported for various ratios of thickness and of inner to outer radii.

Rectangular Plates

Triangular and quadrilateral finite elements have been used [124] to analyze simply supported and clamped rectangular plates. Finite elements have also been used [119]. The first 13 frequencies of a simply supported rectangular plate having a thickness ratio of 1/10 and an aspect ratio of $\sqrt{2}$ have been reported [125]. Orthotropic effects were also studied. The effects of in-plane stress have been included [126, 127]. Reismann and Tendorf [126] presented results for the simply supported plate having a thickness ratio of 1/10 and an aspect ratio of $\sqrt{2}$ for the case of uniform in-plane stress (tension or compression) in one direction. Brunelle and Robertson [127] considered the effects of both axial stress N_x and axial moment M_x, with both bending and extensional deformation, upon a simply supported plate. In another paper [128] they treated transversely isotropic plates having the same types of in-plane stress. The effects of large deflections upon the vibration of thick plates have been investigated [129]. Results were given for the simply supported square.

Other work deals with thick plates [130-133]. Vibrations of thick orthotropic plates have been used to determine elastic properties experimentally [130].

NONHOMOGENEOUS PLATES

Material properties of a plate can vary with its length coordinates (say x or y) or with its thickness coordinate (z). The properties can vary continuously or in a step-wise manner. Examples of the former include materials that can vary widely in modulus of elasticity naturally (e.g., rubber, styrofoam) or as a result of severe thermal gradients [67]. Examples of the latter are layered plates, including those made of fibrous composite layers, which are of great importance in advanced plate design.

For layered plates the differential equation of motion (1) must be generalized by a piecewise integration of the forces and moments over the thickness of the plate, and, unless the layer arrangement is symmetrical with respect to the midplane of the plate, bending and stretching of the midplane are coupled during plate deformation. It has been shown by Reissner and Stavsky [134], Whitney and Leissa [135], and many others that the effect of the coupling is often significant with respect to vibration frequencies.

General problems of vibrating nonhomogeneous plates [67, 136-138] include the effects of materials with continuously varying properties. Many recent publications have dealt with vibrations of layered (laminated) plates [119, 139-175]. The effects of initial, in-plane forces have been treated [139-143], and nonlinear (large deflection) vibrations have been studied [144-148]. Bert [149] wrote an excellent survey paper on the vibrations of layered plates, with special emphasis on the effects of damping.

SUMMARY

In the previous paper of this series [1] it was shown that considerable research in the vibration of plates is governed by classical plate theory. It was conjectured that probably more research on classical plate vibrations has been done and reported since the beginning of 1966 than in all time previous [2].

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BOOK REVIEWS

COMPUTING IN APPLIED MECHANICS

R.F. Hartung, Editor
The American Society of Mechanical Engineers
New York, 1976

This book is a collection of nine papers that were presented at the ASME Winter Annual Meeting in New York in December 1976. The papers comprised a symposium organized by the Applied Mechanics Division's Committee on Computing to highlight various aspects of computerized analysis in applied mechanics.

Schaeffer's paper has to to with the advances in computer hardware, numerical analysis, and computer science and discusses his perception of future finite element analysis codes using NASTRAN as a base line. He identifies developments required in supporting technological areas and discusses the concept of a National Software Center to disseminate valuable software resources.

Smith and Craig consider the role of the minicomputer in experimental mechanics. They describe appropriate hardware and software and provide examples of effective systems.

Vanderplaats considers the role of the computer in design synthesis. He describes numerical optimization techniques and discusses methods of coupling these techniques with analysis procedures to achieve fully automated design capability.

MacCormic's paper is concerned with the field of computational fluid mechanics. He presents a new numerical technique for solving such systems of equations as the time-dependent Navier-Stokes equations at high Reynolds numbers.

Gartling reviews recent developments in the use of the finite element to solve problems of viscous incompressible flow. He also discusses the coupled fluid/thermal problem and presents problem formulations, solution methods, and example problems.

The paper by Egan et al discusses interesting applications of the computer to environmental studies. Two broad categories are defined: computer simulation in the analysis of air pollution and data acquisition and storage for environmental studies.

Tong describes computational methods used to analyze dynamic problems associated with ground transportation. The four specific problem areas discussed are vehicle crashworthiness prediction, rail vehicle dynamics, and train handling and track wear.

Belytschko considers methods for computer analysis of wave propagation and shock. The methods are categorized as methods of characteristics, semi-discretization methods, and hybrid methods.

Finally Bathe surveys the computational methods for analysis of problems in structural dynamics. He presents the numerical formulation and discusses methods appropriate for linear and nonlinear analyses.

The book contains a brief summary of each paper by Hartung; the sympsoium organizer; he draws the following general conclusions.

- The computer, coupled with computer-oriented computational schemes, has been instrumental in achieving the level of sophistication that exists in many areas of applied mechanics.
- Further advances in computational applied mechanics will depend more upon advances in computer technology and numerical analysis than upon breakthroughs in applied mechanics.
- Computational methods are a common ingredient in work being done in most areas of applied mechanics. At the computational level many of the different areas begin to look similar.

The computer may well serve the purpose of promoting more interdisciplinary work within applied mechanics.

- The use of the computer in design (as opposed to analysis) remains limited, primarily because of high computer costs. As more powerful computing hardware becomes available, the computer will become an important design tool in applied mechanics.
- Dynamic problems are common to many areas of applied mechanics, and their solution is presently receiving much attention. New numerical integration methods that are being developed will lead to more solutions per computer dollar.
- A vast national resource exists in the many computer programs that have been developed in applied mechanics and other fields of technology. No one has yet found a satisfactory solution for disseminating, maintaining, and providing technical support for these programs.
- The use of computers for data acquisition, data reduction, and control of experiments has become more common with the advent of low cost, high power minicomputers.

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THE COMPONENT ELEMENT METHOD IN DYNAMICS

S. Levy and J.P.D. Wilkinson
McGraw-Hill Book Company, New York, NY

Many dynamics books are published, but this is one of the more outstanding ones because it contains topics concerned with current design problems. Subjects usually found only in specialized volumes are included: finite elements, structurally-induced vibrations, vehicle dynamics, turbine bucket analysis under centrifugal loads, and earthquake design. The nine chapters progress from elementary to more advanced vibration topics.

Chapter I is concerned with force, mass, damping, and stiffness; forced response is included, as is a good discussion of the Newmark, Houbolt, and Wilson methods applied to the dynamic response of linear and nonlinear systems.

Chapter II has to do with the dynamics of single-mass systems and nonlinearities of springs and dampers. A fully detailed computer program used by the authors in the past few years is included.

Chapter III describes multi-degree-of-freedom systems in matrix notation and applies the information to beam dynamics and forced responses of linear and nonlinear systems. The stiffness matrix of a beam with shear deformation is considered, and an extensive computer program developed by the authors is given.

Chapter IV begins with basic linear and nonlinear problems and goes on to applied engineering problems; i.e., vehicle dynamics, aircraft landings, locomotive dynamics, car (train) dynamics, and air-cushion vehicle dynamics. This information is not available in any other book.

In the reviewer's opinion Chapter V on finite elements is excellent. Few dynamics books even discuss finite elements. The simple spring is described first, then two-dimensional elastic continuum and isoparametric elements. Three-dimensional solid elements are described for the first time in a book on dynamics.

Chapter VI, a continuation of the previous chapter, includes information on the direct use of Eigenvalue solutions via Jacobi's method, the Eigenvalue economizer method, and more modern iterative approaches. The reviewer commends the authors for their inclusion of the dynamics of a turbine blade subjected to centrifugal forces -- another first in a dynamics book and also a practical engineering problem in stiffness matrix form.

Chapter VII applied the methods from Chapter VI to the direct response of composite aircraft fan blades and includes a description of impact loading.

Chapter VIII considers the study of seismic response of power plants with finite elements. Design response spectra, generation of artificial design response spectra, substructuring, and soil-structure interaction are included. There is a good section on component mode synthesis.

The final chapter discusses vibration of structural components submerged in water. The subject is directly applicable to reactor internals, marine design, and heat exchanger design. The study of fluid dynamics using finite elements is briefly discussed.

In summary, the book is well written and contains much information not found in many dynamics books. The reviewer would have liked a section on random vibrations and a section on variational methods. The transfer matrix method is not discussed even though many engineers use this version of dynamic analysis. Nevertheless, the book is recommended to persons involved in dynamics.

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BOOK REVIEWS: 1978

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Syndararajan, C., Dynamic Analysis of Pressure Vessel and Piping Components, American Society of Mechanical Engineers, New York; 1977, Reviewed by P.S. Chopra, SVD, 10 (11), p 33 (Nov 1978)

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Developments in Mechanics, Volume 8, Proceedings fo the 14th Midwestern Mechanics Conf.; Reviewed by L.Y. Bahar, SVD, 10 (8), pp 37-38 (Aug 1978)

SHORT COURSES

DECEMBER

MACHINE PROTECTION AND MALFUNCTION DIAGNOSIS

Dates: December 11-15, 1978
Place: Carson City, Nevada
Objective: Topics to be covered include: Measuring and monitoring parameters for predictive maintenance; Eddy current probe and proximitor theory of operation; Installation procedures and common pitfalls; Permanent machine monitoring systems; System calibration procedures; Thrust position measurements; Troubleshooting the system; Transducer polarity rules; Hazardous area considerations; Introduction to machine data acquisition; Oscilloscope theory and operation; Oscilloscope cameras; Tunable filters, Vector filter-phase meter; Tape recorders; Keyphasor theory; and Electrical runout.

Contact: Training Manager, Bently Nevada Corporation, P.O. Box 157, Minden, Nevada 89423 - (702) 782-3611.

1979

JANUARY

NONDESTRUCTIVE EXAMINATION

Dates: Repeated continuously through-out the year (1 day to 3 weeks)
Place: Los Angeles, CA
Objective: For those requiring qualification and certification, theory and practical application courses are available for either one or all of the basic techniques; Ultrasonics, Radiographic, Magnetic Particle, Liquid Penetrant, Eddy Current and Helium Leak. Also Special Radiation Safety and Radiographic Film Interpretation courses for Level II and Level III training are presented. The selection of courses is also applicable to those who require engineering understanding, supervision training or state-of-the-art development.

Contact: C.A. Parker, Nuclear Training Center, Atomics International, P.O. Box 309, Canoga Park, CA 91304 - (213) 341-1000, Ext. 2811.

STRUCTURED PROGRAMMING AND SOFTWARE ENGINEERING

Dates: January 8-12, 1979
Place: The George Washington University
Objective: This course provides up-to-date technical knowledge of logical expression, analysis, and invention for performing and managing software architecture, design, and production. Presentations will cover principles and applications in structures programming and software engineering, including stepwise refinement, program correctness, and top-down system development.

Contact: Continuing Engineering Education Program, George Washington University, Washington, D.C. 20052 - (202) 676-6106 or toll free (800) 424-9773.

ENVIRONMENTAL ACOUSTICS

Dates: January 10 to March 21, 1979
(Wednesdays, 7-10 p.m.)
Place: UCLA Extension, Los Angeles, CA
Objective: This course will cover acoustic measurements, noise metrics and human criteria, sound propagation and attenuation, vehicle and aircraft noise, sound in rooms, acoustic properties of materials, transmission loss, ducts and mufflers, sound transmission in buildings, vibration control and impact isolation, sound reinforcement, noise law and environmental impact.

Contact: Barbara Marcus, UCLA Extension, P.O. Box 24902, Los Angeles, CA 90024 - (213) 825-1901.

SHOCK AND VIBRATION ENGINEERING FOR AEROSPACE SYSTEMS

Dates: January 9 to March 20, 1979
(Tuesdays, 7-10 p.m.)

Place: UCLA Extension, Los Angeles, CA
Objective: This course will cover each facet of shock and vibration engineering in aerospace systems.

Contact: Barbara Marcus, UCLA Extension, P.O. Box 24902, Los Angeles, CA 90024 - (213) 825-1901.

FEBRUARY

VIBRATION AND LOOSE PARTS MONITORING SYSTEMS AND TECHNOLOGY
Dates: February 5-8, 1979
Place: Los Angeles, California
Objective: A course designed for users, utility designers specifying systems, installers, operators, and analysts of Vibration and Loose Parts Monitoring Systems. Classroom instruction in theory, installation, calibration, alarms and location, signature analysis, noise analysis, and troubleshooting and servicing. Practical demonstration includes student "hands-on" operation of equipment.

Contact: C.A. Parker, Nuclear Training Center, Atomics International, P.O. Box 309, Canoga Park, CA 91304 - (213) 341-1000, Ext. 2811.

FLOW-INDUCED VIBRATION PROBLEMS AND THEIR SOLUTIONS IN PRACTICAL APPLICATIONS: TURBOMACHINERY, HEAT EXCHANGERS AND NUCLEAR REACTORS
Dates: February 12-16, 1979
Place: The University of Tennessee Space Inst.
Objective: The aim of the course is to provide practicing engineers engaged in design, research and service, an in-depth background and exposure to various problems and solution techniques developed in recent years. Topics to be covered will be the fundamental principles of unsteady fluid flow, structural vibration and their interplay; review of the morphology of flow-induced vibration; state-of-the-art discussion upon theory, experimental techniques and their interaction; methodology of alleviation.

Contact: Jules Bernard, The University of Tennessee Space Institute, Tullahoma, TN 37388 - (615) 455-0631 - Ext. 276 or 277.

MACHINERY VIBRATIONS COURSE
Dates: February 26-March 1, 1979
Place: Shamrock Hilton Hotel, Houston, Texas
Objective: This course on machinery vibrations will cover physical/mathematical descriptions, calculations, modeling, measuring, and analysis. Machinery vibrations control techniques, balancing, isolation, and damping, will be discussed. Techniques for machine fault diagnosis and correction will be reviewed along with examples and case histories. Torsional vibration measurement and calculation will be covered.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, Suite 206, 101 W. 55th St., Clarendon Hills, IL 60514 - (312) 654-2254/654-2053.

MARCH

MACHINERY VIBRATION SEMINAR
Dates: March 6-8, 1979
Place: New Orleans, Louisiana
Objective: To cover the basic aspects of rotor-bearing system dynamics. The course will provide a fundamental understanding of rotating machinery vibrations; an awareness of available tools and techniques for the analysis and diagnosis of rotor vibration problems; and an appreciation of how these techniques are applied to correct vibration problems. Technical personnel who will benefit most from this course are those concerned with the rotor dynamics evaluation of motors, pumps, turbines, compressors, gearing, shafting, couplings, and similar mechanical equipment. The attendee should possess an engineering degree with some understanding of mechanics of materials and vibration theory. Appropriate job functions include machinery designers; and plant, manufacturing, or service engineers.

Contact: Mr. Frank Ralbovsky, MTI, 968 Albany-Shaker Rd., Latham, NY 12110 - (518) 785-2349.

MEASUREMENT SYSTEMS ENGINEERING
Dates: March 12-16, 1979
Place: Phoenix, Arizona
MEASUREMENT SYSTEMS DYNAMICS
Dates: March 19-23, 1979
Place: Phoenix, Arizona
Objective: Program emphasis is on how to increase

productivity, cost-effectiveness and data-validity of data acquisition groups in the field and in the laboratory. The program is intended for engineers, scientists, and managers in industrial, governmental, and educational organizations. Electrical measurements of mechanical and thermal quantities are the major topics.

Contact: Peter K. Stein, 5602 E. Monte Rosa, Phoenix, AZ 85018 - (602) 945-4603/946-7333.

APPLICATIONS OF THE FINITE ELEMENT METHOD TO PROBLEMS IN ENGINEERING

Dates: March 12-16, 1979
Place: The University of Tennessee Space Inst.
Objective: This course will concentrate on material developed recently and provide a solid foundation for those relatively new to the field. Topics to be covered are the treatment of mixed type equations which occur in transonic flow and wave motion in nonlinear solids, mixed type elements which are of importance in systems such as the Navier-Stokes equations, the interrelationship between the equation formation and the iterative scheme needed to solve any of the nonlinear equations, the advantages of hybrid elements, and the use of interactive graphics as an aid to problem solution.

Contact: Jules Bernard, The University of Tennessee Space Institute, Tullahoma, TN 37388 - (615) 455-0631, Ext. 276 or 277.

APRIL

CORRELATION AND COHERENCE ANALYSIS FOR ACOUSTICS AND VIBRATION PROBLEMS

Dates: April 16-20, 1979
Place: UCLA
Objective: This course covers the latest practical techniques of correlation and coherence analysis (ordinary, multiple, partial) for solving acoustics and vibration problems in physical systems. Procedures currently being applied to data collected from single, multiple and distributed input/output systems are explained to: classify data and systems; measure propagation times; identify source contributions; evaluate and monitor system properties, predict output responses and noise conditions; determine nonlinear and nonstationary effects; and conduct dynamics test programs.

Contact: P.O. Box 24902, Continuing Education in Engineering and Mathematics, UCLA Extension, Los Angeles, CA 90024 - (213) 825-3344/825-1295.

MAY

STRUCTURED PROGRAMMING AND SOFTWARE ENGINEERING

Dates: May 21-25, 1979
Place: The George Washington University
Objective: This course provides up-to-date technical knowledge of logical expression, analysis, and invention for performing and managing software architecture, design, and production. Presentations will cover principles and applications in structures programming and software engineering, including stepwise refinement, program correctness, and top-down system development.

Contact: Continuing Engineering Education Program, George Washington University, Washington, D.C. 20052 - (202) 676-6106 or toll free (800) 424-9773.

JUNE

ACOUSTIC EMISSION STRUCTURAL MONITORING TECHNOLOGY

Dates: June 18-19, 1979
Place Los Angeles, California
Objective: A theory and practice course covering each of the various facets of acoustic emission structural monitoring technology; basic phenomena, state-of-the-art applications, field testing experience, applicable codes and standards and instrumentation design and calibration. Includes "hands-on" operation of minicomputer and microcomputer acoustic emission systems. This course is designed for potential users of acoustic emission structural monitoring systems.

Contact: C.A. Parker, Nuclear Training Center, Atomics International, P.O. Box 309, Canoga Park, CA 91304 - (213) 341-1000, Ext. 2811.

NEWS BRIEFS

news on current and Future Shock and Vibration activities and events

CALL FOR PAPERS
Design and Applications: Advanced Composite Materials

The Mechanical Failure Prevention Group (MFPG) sponsored by the National Bureau of Standards; Office of Naval Research, Department of the Navy; Department of Energy; and NASA Goddard Space Flight Center will hold its 29th Symposium at the National Bureau of Standards, Gaithersburg, Maryland on May 22-24, 1979. Papers are desired in the following areas: Applications in land, marine, and aerospace systems; Analytical techniques; Fabrication techniques; Non-destructive testing; Failure modes; Environmental effects; and Materials. Proceedings in the form of extended abstracts, 2-4 typewritten pages, will be published by the National Bureau of Standards. Closing date for initial abstracts is January 1, 1979 and for extended abstracts, April 30, 1979. Abstracts should be sent to Jesse E. Stern, Code 721, Goddard Space Flight Center, Greenbelt, Maryland 20771 - (301) 982-2657.

VIBRATION OF BEARINGS

The book Vibration of Bearings by K.M. Ragulskis, A.Y. Jurkauskas, V.V. Atstupenas, A.Y. Vitkute, and A.P. Kulvec has been translated into English by NASA (Rept. No NASA-TT-F-17449; TT-75-52090, 517 pp (Dec 1977)[Engl. transl. of "Vibratsiya podshipnikov" Vilnius, Lit. SSR: Mintis Publishers; 1974, 391 pp]). It contains analytical determination of vibrations and friction torque due to rotation taking into account the hydrodynamic action of a lubricating oil film. Determination of the elastic and damping characteristics of bearings and bearing assemblies are some of the problems considered in this book. The methodology and techniques of measuring the dynamic characteristics of bearings are presented. Experimental data and the methodology of statistical analysis are also given. The Russian version of the book was reviewed in the December 1977 issue of the DIGEST.

ABSTRACT CATEGORIES

ANALYSIS AND DESIGN

Analogs and Analog Computation
Analytical Methods
Dynamic Programming
Impedance Methods
Integral Transforms
Nonlinear Analysis
Numerical Analysis
Optimization Techniques
Perturbation Methods
Stability Analysis
Statistical Methods
Variational Methods
Finite Element Modeling
Modeling
Digital Simulation
Parameter Identification
Design Information
Design Techniques
Criteria, Standards, and Specifications
Surveys and Bibliographies
Tutorial
Modal Analysis and Synthesis

COMPUTER PROGRAMS

General
Natural Frequency
Random Response
Stability
Steady State Response
Transient Response

ENVIRONMENTS

Acoustic
Periodic
Random
Seismic
Shock
General Weapon
Transportation

PHENOMENOLOGY

Composite
Damping
Elastic
Fatigue
Fluid
Inelastic
Soil
Thermoelastic
Viscoelastic

EXPERIMENTATION

Balancing
Data Reduction
Diagnostics
Equipment
Experiment Design
Facilities
Instrumentation
Procedures
Scaling and Modeling
Simulators
Specifications
Techniques
Holography

COMPONENTS

Absorbers
Shafts
Beams, Strings, Rods, Bars
Bearings
Blades
Columns
Controls
Cylinders
Ducts
Frames, Arches
Gears
Isolators
Linkages
Mechanical
Membranes, Films, and Webs
Panels
Pipes and Tubes
Plates and Shells
Rings
Springs
Structural
Tires

SYSTEMS

Absorber
Acoustic Isolation
Noise Reduction
Active Isolation
Aircraft
Artillery
Bioengineering
Bridges
Building
Cabinets
Construction
Electrical
Foundations and Earth
Helicopters
Human
Isolation
Material Handling
Mechanical
Metal Working and Forming
Off-Road Vehicles
Optical
Package
Pressure Vessels
Pumps, Turbines, Fans, Compressors
Rail
Reactors
Reciprocating Machine
Road
Rotors
Satellite
Self-Excited
Ship
Spacecraft
Structural
Transmissions
Turbomachinery
Useful Application

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI; U.S. Patents from the Commissioner of Patents, Washington, D.C. 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

ABSTRACT CONTENTS

ANALYSIS AND DESIGN

ANALYTICAL METHODS

(Also see No. 1820)

78-1700

Eigenvalue Bounds for Damped Linear Systems

D.W. Nicholson
Goodyear Research, The Goodyear Tire and Rubber Co., Akron, OH, Mech. Res. Comm., 5 (3), pp 147-152 (1978) 4 refs

Key Words: Free vibration, Boundary value problems, Linear systems, Damped structures

Lower bounds are obtained on the real and imaginary parts of the eigenvalues of a damped linear system in free vibration. A condition for subcritical damping in all modes is obtained. The bounds have a close relation to the eigenvalue of a one degree-of-freedom system.

78-1701

Methods for Oscillating Problems

L. Petzold and G.W. Gear
Dept. of Computer Science, Illinois Inst. of Tech., Chicago, IL, Rept. No. C00-2383-45; UILU-ENG-77-1752, 36 pp (Oct 1977)
N78-23826

Key Words: Boundary value problems

Initial-value problems for ordinary differential equations with highly oscillatory solutions are considered. A solution method, applicable to linear or nonlinear oscillations, is discussed.

NONLINEAR ANALYSIS

78-1702

A Boundary Tracking Optimization Algorithm for Constrained Nonlinear Problems

J.Y. Morado and M. Pappas
Dept. of Mech. Engrg., Newark College of Engrg. of the New Jersey Inst. of Technology, Newark, NJ, J. Mech. Des., Trans. ASME, 100 (2), pp 292-296 (Apr 1978) 1 fig, 4 tables, 13 refs

Key Words: Nonlinear programming, Optimization

A new procedure for numerical optimization of constrained nonlinear problems is described. The method makes use of an efficient "boundary tracking" strategy to move on the constraint surfaces. In a comparison study it was found to be an effective method for treating nonlinear mathematical programming problems particularly those with difficult nonlinear constraints.

NUMERICAL ANALYSIS

78-1703

Numerical Solutions of the Unsteady Transonic Small-Disturbance Equations

M.M. Hafez, M.H. Rizk, E.M. Murman, and L.C. Wellford
Flow Research Co., Kent, WA, Rept. No. FLOW-RR-83, AFFDL-TR-77-100, 68 pp (Oct 1977)
AD-A054 036/9GA

Key Words: Numerical analysis, Fluid mechanics, Perturbation theory, Harmonic waves, Finite element technique

Three problems pertinent to the numerical solution of the unsteady transonic small-disturbance equation are studied. The first problem is the numerical instabilities arising in the solution of the harmonic perturbation potential equation. Several remedies that have been tested are suggested. The second problem is the movement of unsteady shock waves in the harmonic perturbation approach. A formulation and computed example are presented. The third problem is a finite-element formulation for unsteady transonic flow. Preliminary calculations are given.

78-1704

Dynamic Analysis of Structures Containing Nonlinear Springs

L.D. Hofmeister
Systems Dev. Corp., 2500 Colorado Blvd., Santa Monica, CA 90406, Computers Struc., 8 (5), pp 609-614 (May 1978) 1 fig, 5 tables, 11 refs

Key Words: Linear systems, Nonlinear springs, Iteration

An efficient algorithm is presented for the solution of the dynamics problem of a linear structure containing springs with nonlinear force-deflection characteristics. The method is based upon the Newmark direct integrator, and uses an iterative procedure in each time step to account for the nonlinear spring behavior. Convergence criteria are derived for the iteration.

OPTIMIZATION TECHNIQUES

(Also see Nos. 1789, 1804, 1821)

78-1705

Sensitivity Analysis and Optimization of Structures for Dynamic Response

E.J. Haug, J.S. Arora, and T.T. Feng

Materials Div., College of Engrg., Univ. of Iowa, Iowa City, IA, J. Mech. Des., Trans. ASME, 100 (2), pp 311-318 (Apr 1978) 6 figs, 5 tables, 12 refs

Key Words: Optimum design, Earthquake resistant structures, Blast resistant structures

A state space method of optimal design of structures under transient dynamic excitation is developed and three problems are solved. It is shown that exploitation of the mathematical form of the equations of structural dynamics leads to significant computational efficiencies. A factor of five reduction in computing time is shown to be achievable, relative to more conventional nonlinear programming methods.

STATISTICAL METHODS

(Also see No. 1819)

78-1706

Statistics of Normal Mode Amplitudes in a Random Ocean. II. Computations

L.B. Dozier and F.D. Tappert

Courant Inst., New York Univ., New York, NY 10012, J. Acoust. Soc. Amer., 64 (2), pp 533-547 (Aug 1978) 8 figs, 1 table, 19 refs

Key Words: Elastic waves, Normal modes, Statistical analysis, Monte Carlo method

Numerical acoustic propagation theory in a canonical model of a random ocean is evaluated and compared to the results of a large-scale Monte Carlo computer simulation. At each of the acoustic frequencies 50, 100, 200, 500, and 1000 Hz, 100 independent realizations of the random acoustic model are obtained.

FINITE ELEMENT MODELING

(Also see No. 1721)

78-1707

Linear Constraint Equations for Continuous Support Conditions in Finite Element Analysis

D.D. Pfaffinger

Fides Trust Co., Zurich, Switzerland, Computers Struc., 8 (5), pp 553-562 (May 1978) 11 figs, 3 tables, 12 refs

Key Words: Plates, Elastic foundations, Finite element technique

Discretized structural models such as by finite elements imply discretized support conditions. In some cases such as plates on elastic foundation or slabs on large interacting columns an improved formulation of the continuous support conditions is desirable. This can be achieved by means of linear constraint equations. The numerical treatment of linear constraints is discussed for the method of elimination of variables as well as for the method of Lagrange multipliers. Then specific constraint equations for different accuracy requirements are derived, which can be used to constrain rectangular flat shell elements of arbitrary shape functions. The effect on the strain energy of a square shell element is shown for the different constraint equations. As an application, the linear constraints are used to represent the continuous interaction of columns with the plate in a flat slab structure. Comparison of the finite element solutions with analytical results shows that the derived constraint equations allow a considerably improved formulation of continuous support conditions.

78-1708

Finite-Element Analysis of Coupled Thermoviscoelastic Structures Undergoing Sustained Periodic Vibrations

T.L. Cost and J.M. Heard

Univ. of Alabama, Tuscaloosa, AZ, AIAA J., 16 (8), pp 795-799 (Aug 1978) 5 figs, 10 refs

Key Words: Forced vibration, Periodic response, Finite element technique, Thermoviscoelasticity theory, Computer programs

A general method is presented for analyzing the effects of internal heating in geometrically complex viscoelastic structures due to exposure to sustained periodic vibratory loads. The analysis employs the finite-element method for both transient displacement and temperature determinations and utilizes "complex" viscoelastic material property functions. The method is demonstrated by application to a problem involving longitudinal oscillations of a linear viscoelastic rod. General agreement is obtained with the results of Huang and Lee which appear in the literature. The method is applicable to geometrically complex, linear viscoelastic structures of the thermorheologically simple type undergoing small deformations. Existing computer codes that model linear elastic materials can be used, with minor modifications, to obtain linear viscoelastic results.

MODELING

78-1709

Dynamic System Simplification: A Time Domain Criterion

R.G. Leonard and E.D. Ward
Automatic Control Center, School of Mech. Engrg., Purdue Univ., West Lafayette, IN 47907, J. Sound Vib., 59 (1), pp 15-21 (July 8, 1978) 6 figs, 1 table, 2 refs

Key Words: Mathematical models, Dynamic systems

This paper explores the conditions under which second and third order dynamic systems can be reduced to systems of lower order. The performance criterion chosen is the 2% settling time in response to a step input to the system. Graphical results are presented which depict the conditions for the valid reduction of second order systems to first order dominant, third order systems to first order dominant, and third order systems to second order dominant.

78-1710

Model Verification of Mixed Dynamic Systems

J.D. Chrostowski, D.A. Evensen, and T.K. Hasselman
Engrg. Mechanics Dept., J.H. Wiggins Co., Redondo Beach, CA, J. Mech. Des., Trans. ASME, 100 (2), pp 266-273 (Apr 1978) 6 figs, 3 tables, 15 refs

Key Words: Mathematical models, Dynamic systems

A general method is presented for using experimental data to verify math models of "mixed" dynamic systems. The term "mixed" is used to suggest applicability to combined systems which may include interactive mechanical, hydraulic, electrical, and conceivably other types of components. Automatic matrix generating procedures are employed to facilitate the modeling of passive networks (e.g., hydraulic, electrical). These procedures are augmented by direct matrix input which can be used to complement the network model. The problem of model verification is treated in two parts; verification of the basic configuration of the model and determination of the parameter values associated with that configuration are addressed sequentially. Statistical parameter estimation is employed to identify selected parameter values, recognizing varying degrees of uncertainty with regard to both experimental data and analytical results. An example problem, involving a coupled hydraulic-mechanical system, is included to demonstrate application of the method.

78-1711

Stored Response Modeling

J. Eichler
Dept. of Mech. Engrg., Ben-Gurion Univ. of the Negev, Beer-Sheva, Israel, J. Dyn. Syst., Meas. and Control, Trans. ASME, 100 (2), pp 132-139 (June 1978) 6 figs, 2 tables, 6 refs

Key Words: Mathematical models, System identification technique, Stored response modeling

A direct "brute force" method of system identification is presented. The method is based on the definition of a deterministic system and applicable to nonlinear nonstationary systems with measurement noise. The approach is to discretize the state of the system (or equivalent measurable state), the input vector and time (in the case of a nonstationary system). An optimal control problem is solved using the SRM model.

PARAMETER IDENTIFICATION

(Also see Nos. 1711, 1868)

78-1712

Instrumental Variables Algorithm for Modal Parameter Identification in Flutter Testing

W. Johnson and N.K. Gupta
Ames Res. Center, NASA, Moffett Field, CA, AIAA J., 16 (8), pp 800-806 (Aug 1978) 4 figs, 1 table, 12 refs

Key Words: Aircraft, Flutter, Testing techniques, Parameter identification technique

An instrumental variables algorithm for modal parameter identification is derived in the frequency domain, and an example of its use in aeroelasticity testing is given. Basically the algorithm fits a set of poles and zeros to the measured transfer function of a linear, time-invariant system. An instrumental variables estimate is similar to a least-squared-error estimate but without the bias of the latter for noisy data. The algorithm was implemented for on-line data reduction using a minicomputer-based analysis system, with less core and computation time requirements than the data acquisition process. With the instrumental variables algorithm, accurate and reliable stability estimates can be obtained from a reasonable length of data.

DESIGN TECHNIQUES

(See No. 1799)

CRITERIA, STANDARDS, AND SPECIFICATIONS

78-1713

Practice and Principle in Environmental Noise Rating

D.W. Robinson

National Physical Lab., Teddington, UK, Rept. No. NPL-Ac-81, 24 pp (Apr 1977)

N78-23885

Key Words: Noise measurement, Standards

The possibility to derive a comprehensive noise index was studied to abandon established practices. Some classes of noise evaluation and planning problems are soluble only within a unified system. These are outlined, together with brief reviews of progress on standardization in UK, USA, and ISO. The scale of noise measurement on which such progress is possible is the A-weighted equivalent continuous sound level, Leq.

78-1714

The Ramifications of Noise Control in Food Plants

W.W. Carey

Nestle Enterprises, Inc., White Plaines, NY, S/V, Sound Vib., 12 (7), pp 22-24 (July 1978) 2 figs, 1 table, 5 refs

Key Words: Noise control, Standards and codes

Current OSHA requirements for engineering control of worker noise exposure conflict with both FDA and USDA sanitation requirements and GMP's for food manufacturing facilities. A comparison of these conflicting requirements is made and examples provided which indicate both the difficulties and magnitude of costs faced by those who must comply with these standards. Approaches being practiced by many processors are reviewed and future actions pertaining to resolution of the Agency conflict are discussed.

78-1715

Locomotive In-Cab Noise -- Towards a Standardized Measurement Methodology

R.M. Clarke, R.D. Kilmer, and D.S. Blomquist

National Bureau of Standards, Washington, D.C., In: NOISE-CON Conf. on Noise Control Engrg., Langley Res. Center, NASA, Hampton, VA, pp 431-442 (Oct 1977)

Sponsored by the Federal Railroad Administration

PB-280 396/3GA

Key Words: Locomotives, Noise measurement, Measurement techniques, Measuring instrumentation, Standards and codes

The U.S. Federal Railroad Administration, in cooperation with the Association of American Railroads, is currently sponsoring efforts by the National Bureau of Standards to collect locomotive in-cab noise level data. The purpose of the program is to develop a simplified stationary test procedure which will correlate with operational duty cycle, crew exposure, and noise level data, and which is based on current OSHA hearing conservation regulations. This paper describes the measurement methodology and instrumentation system developed for this program. The data and conclusions presented are preliminary in nature. The program is scheduled for completion in early 1978.

78-1716

The National Measurement System for Acoustics

D.S. Pallett and M.A. Cadoff

National Bureau of Standards, Washington, D.C., Sound and Vibration 11, No. 10, pp 20-25, 27-31 (Oct 1977)

Key Words: Noise measurement, Measurement techniques, Standards and codes

Many recent acoustical measurement processes have been motivated by societal concern over noise and have broad relevance to our contemporary technological society. The emphasis of the study of the National Measurement for Acoustics has been to determine the adequacy of these important physical measurements and to promote improvements within the measurement system. The relevant physical quantities are indicated, and the interactions occurring between participants as well as the roles of acoustical standardization institutions are specified. Finally, the status and trends of the system and the NBS role in adapting to changing technology are discussed.

78-1717

Earthquake Ordinances for the City of Los Angeles, California. A Brief Case Study

K.A. Solomon, D. Okrent, and M. Rubin

Dept. of Chemical, Nuclear and Thermal Engrg., California Univ., Los Angeles, CA., Rept. No. UCLA-ENG-7765, NSF/RA-770485, 62 pp (Oct 1977) PB-280 763/4GA

Key Words: Buildings, Earthquake-resistant structures, Regulations

The objective of this paper is to illustrate some of the difficulties in dealing with decisions involving the building code revisions designed to protect against earthquake hazards. Discussed are: the history of earthquakes in the Los Angeles area; recent proposed earthquake ordinances; public sentiment regarding earthquake ordinances (as depicted in newspaper editorials); and comparisons of earthquakes risk for unimproved and improved pre-1933 structures. An appendix contains a brief UCLA report on the situation, as perceived in April 1976, and a copy of a briefing given to Governor Brown by the U.S. Geological Survey in March 1976.

SURVEYS AND BIBLIOGRAPHIES

78-1718

Structural Mechanics Software. Volume 2. May 1975 - May 1978 (A Bibliography with Abstracts)

G.W. Reimherr

National Technical Information Service, Springfield, VA., 219 pp (June 1978)
NTIS/PS-78/0551/8GA

Key Words: Bibliographies, Computer programs, NASTRAN (computer program), EPSOLA (computer program), SUPERSCEPTRE (computer program), SINGER (computer program)

The use of computer programs in structural analysis-design problems are cited. Detailed analyses are included of structural problems -- applied and theoretical -- including stress analysis, vibration, deformation, etc. The major computer programs cited in this report are NASTRAN, EPSOLA, SUPERSCEPTRE, and SINGER. (This updated bibliography contains 213 abstracts, 63 of which are new entries to the previous edition.)

78-1719

Highway Traffic Noise (A Bibliography with Abstracts)

E. Kenton

National Technical Information Service, Springfield, VA, 190 pp (June 1978)
NTIS/PS-78/0634/2GA

Key Words: Bibliographies, Traffic noise

The citations relate to many aspects of highway noise and its reduction. Studies include transportation noise models, environmental aspects, noise sources, tire-pavement studies, noise barrier design, noise levels, and research in the field. The bibliography also covers highway planning and Government policies in connection with noise pollution abatement and control strategies. Central city investigations are in general excluded.

78-1720

Stability Tests for One, Two, and Multidimensional Linear Systems

E.I. Jury

Dept. of Electrical Engrg. and Computer Sciences, Electronics Res. Lab., Univ. of California, Berkeley, CA 94720, J. Dyn. Syst., Meas. and Control, Trans. ASME, 100 (2), pp 105-109 (June 1978) 39 refs

Key Words: Reviews, Stability, Linear systems

This paper reviews analytical stability tests for one-dimensional linear systems since the early tests of E.J. Routh in his famous Adams Prize essay of 1877. The historical background of Routh's stability test and criterion, as well as Fuller's conjecture on its simplification, will be mentioned. In this historical review, the works of Hermite, Sylvester, Maxwell and others as related to the stability problem are also discussed. This review provides the context for a discussion of recent stability tests obtained for two-dimensional and multidimensional linear systems. These tests are described and their computational complexity is discussed in detail. In addition, the applications of stability testing to the study of two- and multidimensional digital filters, numerical analysis of stiff-differential equations, realization of mixed lumped and distributed parameter systems, and the design of output feedback systems will be briefly mentioned. Comments on future research in this area concludes the paper.

78-1721

Finite Element Analysis of Structures Under Moving Loads

F.V. Filho

Faculty of Civil Engrg., COPPE, Federal University of Rio de Janeiro, Brazil, Shock Vib. Dig., 10 (8), pp 27-35 (Aug 1978) 5 figs, 2 tables, 36 refs

Key Words: Reviews, Finite element technique, Moving loads

This review is concerned with the utilization of the finite element method to obtain stiffness (or flexibility) properties and the properties of the mass of the structural system and of the mass of the loading due to a moving vehicle. A general equation is formulated and specific cases and their methods of solution are described. Significant contributions are reviewed and related whenever possible to work involving continuous or approximate approaches. Areas of further research are indicated.

78-1722

On Seismic Waves. Part IV: Mathematical Methods (2)

S. De

Old Engrg. Office (Qrs.), Santinketan, Birbhum, West Bengal, India, Shock Vib. Dig., 10 (8), pp 11-26 (Aug 1978) 173 refs

Key Words: Reviews, Seismic waves, Earthquake prediction

This second article on mathematical methods includes a brief discussion about earthquake prediction. Suggestions for future research are given in this final section.

78-1723

Damping Overhead Transmission Line Vibration

C.F. Beards

Dept. of Mech. Engrg., Imperial College of Science and Tech., London SW7 2BX, UK, Shock Vib. Dig., 10 (8), pp 3-8 (Aug 1978) 17 refs

Key Words: Reviews, Cables (ropes), Transmission systems, Suspended structures

Aeolian vibration of overhead transmission lines can cause line failure through fatigue of the conductor, clamps, or supports. Controlling the vibration to keep dynamic stresses at acceptable levels is essential. The cause of aeolian vibration is reviewed, and several methods for controlling it are presented.

MODAL ANALYSIS AND SYNTHESIS

(See Nos. 1742, 1844, 1889, 1890)

COMPUTER PROGRAMS

GENERAL

(Also see Nos. 1718, 1739)

78-1724

Computer Program for Vibration Prediction of Fighter Aircraft Equipments

R.W. Sevy and M.N. Haller

Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH, Rept. No. AFFDL-TR-77-101, 218 pp (Nov 1977)

AD-A054 598/8GA

Key Words: Aircraft equipment, Vibration prediction, Computer programs

This study details in-house efforts that culminate in a computer program for the prediction of vibration inputs to equipments mounted in fighter aircraft. Program inputs specify flight conditions, aircraft structural classes, equipment weight, equipment locational coordinates, and mounting categories in order to characterize vibration inputs of fighter aircraft equipments during flight attitudes ranging from straight and level states to a variety of significant flight maneuvers and phases. Program outputs, digital and graphical, are designed to provide the direct spectral information necessary to assemble sequential vibration histories corresponding to fighter aircraft mission profiles.

78-1725

General Aviation Airplane Structural Crashworthiness User's Manual. Volume II. Input-Output Techniques and Applications

M.A. Gamon, G. Wittlin, and W.L. LaBarge

Lockheed-California Co., Burbank, CA, Rept. No. LR-28307-VOL-2, FAA-RD-77-189-VOL-2, 185 pp (Feb 1978)

AD-A054 317/3GA

Key Words: Computer programs, Collision research (aircraft)

This document provides a comprehensive description of program KRASH as modified. Included in this Volume of the User's Manual are the following sections: user's guide, math model development; KRASH data requirements; and Typical Model Arrangements.

78-1726

General Aviation Airplane Structural Crashworthiness User's Manual. Volume III. Related Design Information

G. Wittlin

Lockheed-California Co., Burbank, CA., Rept. No. LR-28307-3, FAA/RD-77/189-3, 121 pp (Feb 1978)

AD-A054 266/2GA

Key Words: Computer programs, Collision research (aircraft)

General information is presented in this report to assist the general aviation airplane industry designer in developing improved structural crashworthiness designs. This report is initiated for the purpose of providing the General Aviation Manufacturers Association (GAMA) members with the basis for understanding the types of procedures, methods and data that are available with regard to structural crashworthiness. This document contains the following sections: (1) General Aviation Airplane Operational and Structural Characteristics; (2) Crash Environment; (3) Occupant Injury Assessment; (4) Structural Data and Methods; and (5) Structural Crashworthiness Design and Compliance Methods.

78-1727

The Digital Calculation of the Operating Parameters of the Mercedes-Benz Accident Simulator (Die digitale Berechnung der Betriebsparameter des Mercedes-Benz Unfallsimulators)

E. Decker and J. Arnemann

Meisenweg 5, 7257 Ditzingen 5, Automobiltech. Z., 80 (6), pp 293-294 (June 1978) 3 figs

Key Words: Collision research (automotive), Computer programs

This paper describes the development of a mathematical model for the accident simulator used at Daimler-Benz, Sindelfingen. The digital computer program predicts the response of the testing for a given set of parameters and will be explained by a practical example.

78-1728

Revision of Simulation Model of Automobile Collisions Computer Program: Investigation of New Integration Algorithm

M. Chi, E. Neal, and J.R. Tucker

Chi Associates, Inc., Arlington, VA., Rept. No. DOT-HS-803 294, 142 pp (May 20, 1977)
PB-280 753/5GA

Key Words: Computer programs, Collision research (automotive)

SMAC (Simulated Model of Automobile Collisions) is a computerized program which recreates collision events between two automobiles. Its purpose is to provide a data bank from which information on the causes and consequences of these accidents can be drawn and to aid highway planners and the public in general to avoid unnecessary accidents and mitigate the effects of those which are unavoidable. Based on preliminary investigation of the new procedure, significant progress has been recorded in reducing computer execution time.

78-1729

Users' Manual for Asymmetric Wheel/Rail Contact Characterization Program

R. Heller and N.K. Cooperrider

Dept. of Mech. Engrg., Arizona State Univ., Tempe, AZ, Rept. No. FRA/ORD-78/05, 103 pp (Dec 1977)
PB-279 707/4GA

Key Words: Interaction: rail-wheel, Computer programs

Wheel/rail geometric constraint relationships, such as the effective conicity and gravitational stiffness, strongly influence the lateral dynamics of railway vehicles. The principal curvatures of wheel and rail profiles are important parameters in the determination of creep coefficients used in rail vehicle models. In general, these geometric constraints and profile curvatures are nonlinear functions of the wheelset lateral displacement. This report is a users manual for a computer program written in Fortran IV that uses iterative procedures to determine these nonlinear functions for arbitrary wheel and rail profiles. The program computes the wheel/rail contact positions, geometric constraint functions, and profile curvatures for any given wheel profile, rail profile, rail cant angle, and rail gauge for an asymmetric wheelset on asymmetric rails. Analytical methods used and program input and output are described. Results are in the form of printout, punched cards and drum plotter plots. The users manual includes program listings, sample deck set-ups, and sample run output.

78-1730

The Inclusion of Coulomb Friction in Mechanisms Programs with Particular Reference to DRAM

D.C. Threlfall

Central Electricity Generating Board, Berkeley Nuclear Labs., Berkeley, Gloucestershire, UK, Mech. Mach. Theory, 13 (4), pp 475-483 (1978) 12 figs, 6 refs

Key Words: Computer programs, Mechanisms, Coulomb friction

This paper discusses some properties of friction and critically assesses several possible methods of incorporating these into automatic mechanism programs. The method selected, its compromises and its incorporation into a particular computer program DRAM (Dynamic Response of Articulated Machinery) are described in detail. This method is shown to be a successful compromise between theoretical studies of friction and the avoidance of large computational overheads in their application.

78-1731

THIN - A Computer Program for Analyzing the Axisymmetric Behavior of Thin Spherical Shells

H.E. Williams
Naval Weapons Center, China Lake, CA, Rept. No. NWC-TP-5785, GIDEP-E053-0467
AD-B007 306/4GA

Key Words: Computer programs, Spherical shells

The computer program THIN obtains the solution of the equations of equilibrium governing the small deflections of thin spherical shells using an algorithm called "Dynamic Relaxation." It is assumed that the material properties of the shell are constant and that the shell is closed at the apex. The conditions at the outer edge can be chosen to be either clamped, simply-supported or supported on a transverse rollerskate. This report describes the input/output requirements of the program, the behavior of the "Dynamic Relaxation" algorithm and estimates the accuracy of the program by comparing numerical results obtained using THIN with either exact analytical solutions or analytical solutions where accuracy can be assessed.

ENVIRONMENTS

ACOUSTIC

(Also see Nos. 1714, 1715, 1716, 1719, 1833, 1845, 1846, 1847, 1849, 1850, 1851, 1852, 1853, 1859, 1870)

78-1732

Classifying Road Vehicles for the Prediction of Road Traffic Noise

P.M. Nelson and R.J. Piner
Transport and Road Res. Lab., Crowthorne, UK, Rept. No. TRRL-LR-752, 26 pp (1977)
PB-280 864/0GA

Key Words: Traffic noise, Noise prediction, Noise measurement

The accuracy of traffic noise predictions obtained using the TRRL computer model of traffic noise depends to a considerable extent on the degree of simplification adopted in categorizing vehicles according to their sound output and speed in the traffic stream. This report examines and summarizes the available data on the acoustic classification of vehicles in traffic streams for predicting traffic noise. Measurements of speed, noise level and vehicle type have been made in road conditions ranging from fairly congested urban situations with speeds around 20 km/h to free flow on motorways with speeds over 100 km/h. The measurements have been used to construct approximate vehicle noise levels and speed characteristics over the speed range 20-100 km/h for up to 6 vehicle categories, and used as input in the TRRL computer model of traffic noise.

78-1733

Traffic Noise in a High-Rise City

N.W.M. Ko
Dept. of Mech. Engrg., Univ. of Hong Kong, Hong Kong, Appl. Acoust., 11 (3), pp 225-239 (July 1978) 3 figs, 3 tables, 16 refs

Key Words: Traffic noise, Urban noise, Noise measurement

Extensive results of traffic noise measured at 258 roadside sites in the high-rise city of Hong Kong are reported. From the results of this investigation the measurement sites can be very simply classified into three categories: enclosed, semi-enclosed and open. Distinct differences were found in the sound pressure levels L_{10}, L_{50} and L_{90} and in the standard deviations obtained at the enclosed site and at the semi-enclosed and open sites.

78-1734

Multiple-Reflection Diffuse-Scattering Model for Noise Propagation in Streets

H.G. Davies
Dept. of Mech. Engrg., Univ. of New Brunswick, Fredericton, New Brunswick, Canada, J. Acoust. Soc. Amer., 64 (2), pp 517-521 (Aug 1978) 4 figs, 5 refs

Key Words: Urban noise, Sound propagation, Acoustic scattering

The sound field generated by an omnidirectional point source in an infinitely long, straight street is considered. The field is assumed to be the sum of a multiply-specularly reflected field and a diffuse field that is fed from scattering at the walls at each reflection of the specular field. It is shown that scattering is important close to the source. The sound level depends on the width of the street and the height of the walls and on the reflection and scattering coefficients of the walls.

78-1735

Noise Transmission Through Plates into an Enclosure

W.B. McDonald
Langley Res. Center, NASA, Langley Station, VA.,

Rept. No. NASA-TP-1173; L-11906, 44 pp (May 1978)
N78-23877

Key Words: Plates, Sound transmission, Enclosures

An analytical model is presented to predict noise transmission through elastic plates into a hard-walled rectangular cavity at low frequencies, that is, frequencies up through the first few plate and cavity natural frequencies. One or several nonoverlapping and independently vibrating panels are considered. The effects on noise transmission of different external-pressure excitations, plate boundary conditions, fluid parameters, structural parameters, and geometrical parameters were investigated.

78-1736

Measurements with an Intensity Meter of the Acoustic Power of a Small Machine in a Room

F.J. Fahy
Inst. of Sound and Vib. Research, Southampton Univ., Southampton S09 5NH, UK, Rept. No. ISVR-TR-94, 27 pp (Sept 1977)
N78-23884

Key Words: Machinery noise, Noise measurement, Measurement techniques

A technique which employs two closely spaced pressure microphones, a special purpose circuit, and a sound level meter to measure acoustic intensity in octave bands, is used to estimate the intensity distribution around a small, 1200 electrical watt, machine situated in a room. The total acoustic power estimated therefrom is compared with that obtained by the conventional direct field method. The technique, which appears to be accurate over the range 250-4000 Hz, produces values of intensity and power which are generally less than the direct field values. The difference tends to increase with frequency. A potential for source location application is indicated.

78-1737

Jet Noise Modelling by Geometric Acoustics. Part 1: Theory and Prediction Outside the Cone of Silence

C.L. Morfey and V.M. Szewczyk
Inst. of Sound and Vib. Research, Southampton Univ., Southampton, UK, Rept. No. ISVR-TR-91-Pt-1, 174 pp (Sept 1977)
N78-23881

Key Words: Jet noise, Noise prediction, Mathematical models

The generation of noise by the turbulent mixing process downstream of a round jet nozzle is investigated and a geometric acoustics model for jet noise radiation outside the cone of silence is developed. For isothermal jets the turbulence is represented as acoustically equivalent to a volume displacement distribution of quadrupole order. For non-uniform density flows (heated jets) the dominant radiation at low Mach numbers is modeled as acoustically equivalent to a volume displacement distribution of dipole order. A volume displacement monopole distribution is also considered as a possible additional source of noise in heated jets. The effect of mean flow-acoustic interaction is modeled separately from the sources. Source non-compactness and convection effects are included in the source description. A jet noise prediction scheme valid for radiation angles outside the cone of silence is developed from the source master spectra and turbulence parameters inferred from rear arc jet noise measurements, using the geometric acoustics model. Agreement between predictions in the forward arc and measured results is very good.

78-1738

Jet Noise Modelling by Geometric Acoustics. Part 2: Theory and Prediction Inside the Cone of Silence

C.L. Morfey and V.M. Szewczyk
Inst. of Sound and Vib. Research, Southampton Univ., Southampton, UK, Rept. No. ISVR-TR-92-Pt-2, 84 pp (Oct 1977)
N78-23882

Key Words: Jet noise, Noise prediction, Mathematical models

A geometric acoustics model of jet mixing noise is extended to describe far-field radiation within the cone of silence. The relevant acoustic-mean flow interactions are modeled by an approximation to the WKB type solution. The original monopole solution is generalized to yield high-frequency solutions for the dipole and quadrupole sources used to model jet mixing noise. The exponential decay factor encountered within the cone of silence is theoretically predicted to be almost proportional (in decibels) to the shear layer thickness. Analysis of a wide range of isothermal jet noise data leads to inferred values of the ratio of shear layer thickness at the source location to the nozzle diameter, as a function of Strouhal number. These are in excellent agreement with the results of source location and flow profile measurements.

78-1739

Jet Noise Modelling by Geometric Acoustics. Part 3: A Computer Program for the Prediction of Jet Mixing Noise

C.L. Morfey and V.M. Szewczyk

Inst. of Sound and Vib. Research, Southampton Univ., Southampton, UK, Rept. No. ISVR-TR-93-Pt-3, 29 pp (Oct 1977)
N78-23883

Key Words: Jet noise, Noise prediction, Computer programs

A prediction program for far-field jet mixing noise is documented. The theory is based upon Morfey's geometric acoustics model of jet mixing noise. The program is valid for radiation angles greater than 30 deg to the jet axis and for any jet static temperature ratio. Any velocity ratio may be predicted outside the cone of silence, but there is at present an upper limit inside the cone of silence. Sound pressure levels in 1/3 octave bands are predicted for a source Strouhal number range of 0.1 to 3.16, corresponding to a frequency range of 5 octaves centered approximately on the peak 1/3 octave frequency.

78-1740

Noise Suppression in Jet Inlets

B. Zinn, W.L. Meyer, and W.A. Bell
School of Aerospace Engrg., Georgia Inst. of Tech., Atlanta, GA., Rept. No. AFOSR-TR-78-0696, 52 pp (Feb 1978)
AD-A054 173/0GA

Key Words: Jet noise, Geometric effects, Numerical analysis, Computer programs

This report summarizes the work performed during the first year of a research effort to determine the sound fields associated with jet engine inlet configurations. A solution approach for axisymmetric bodies based upon the integral formulation of the wave equation has been developed. This solution approach circumvents the uniqueness problems which normally occur at certain frequencies when 'straightforward' solutions of the integral equation are obtained. A numerical method and a computer program for solving for the acoustic field associated with general inlet configurations and boundary conditions have also been developed. To evaluate the numerical method, computed and exact results are compared for a sphere and a finite length cylinder. For continuous boundary conditions, the agreement is within ten per cent over a range of nondimensional frequencies from one to ten. For discontinuous boundary conditions, the numerical errors increased by a factor of two. This report presents results for a given inlet configuration and the computed and exact solutions are shown to agree to within ten per cent over the nondimensional frequency range from one to ten.

78-1741

Experimental Measurements of Acoustic Scattering by Rows of Cylindrical Obstacles

S. Liao and W. Sachse
Dames & Moore, Cranford, NJ 07016, J. Acoust. Soc. Amer., 64 (2), pp 563-570 (Aug 1978) 11 figs, 14 refs

Key Words: Underwater sound, Acoustic scattering, Cylinders

Experiments were performed in a shallow two-dimensional water tank to determine the effects of diameter, spacing, and material properties on acoustic scattering by rows of cylindrical obstacles. Cylinder diameters ranged from 0.17 to 0.39 times the wavelength, and center-to-center spacings up to 1.2 wavelengths were investigated. In the limit of small spacings, multiple scattering was found to be characteristically similar to sound wave transmission through walls. Analysis of the experimental data indicated that the acoustic properties and microstructure of the scatterers could be distinguished by the transmissivity response of the arrays.

RANDOM

(See Nos. 1781, 1782)

SEISMIC

(Also see Nos. 1705, 1717, 1722, 1799, 1828, 1858, 1876)

78-1742

Simulation of Strong-Motion Displacements Using Surface-Wave Modal Superposition

H.J. Swanger and D.M. Moore
Dept. of Geophysics, Stanford Univ., Stanford, CA 94305, Bull. Seismol. Soc. Amer., 68 (4), pp 907-922 (Aug 1978) 10 figs, 4 tables, 27 refs

Key Words: Ground motion, Simulation, Modal synthesis

Synthetic seismograms constructed by addition of surface-wave modes in a layered half-space are compared to Cagniard-de Hoop calculations of Heaton and Helmberger (1977, 1978) and to ground displacement recordings near El Centro, California to examine the applicability of modal superposition as a means of simulating ground motion of possible engineering interest. Ground displacement recordings of El Centro from the 1968 Borrego Mountain earthquake are modeled using a multi-layered geological structure and a source model based on independent studies.

78-1743

New Discrete Models and Their Application to Seismic Response Analysis of Structures

T. Kawai
Inst. of Industrial Science, Univ. of Tokyo, 22-1, Roppongi 7 Chome, Minato-ku, Tokyo 106, Japan,
Nucl. Engr. Des., 48 (1), pp 207-229 (June 1978) 34 figs, 2 tables, 14 refs

Key Words: Lumped parameter methods, Seismic response

New discrete models and their application to seismic response analysis of structures is proposed in this paper. These models consist of finite number of small rigid bodies connected with springs distributed over the contact area of two neighboring bodies. In general size of stiffness matrices of these elements are at most (6 X 6) which are equal to or even smaller than ½ of those of conventional finite elements so that considerable reduction of computing time can be expected. Effectiveness of these elements in nonlinear structural analysis, especially dynamic response analysis of structures are demonstrated by several numerical examples.

78-1744

Torsional Spectrum for Earthquake Motions

W.K. Tso and T.-I. Hsu
Dept. of Civil Engrg. and Engrg. Mechanics, McMaster Univ., Hamilton, Ontario, Canada,
Intl. J. Earthquake Engr. Struc. Dynam., 6 (4), pp 375-382 (July/Aug 1978) 6 figs, 1 table, 7 refs

Key Words: Seismic excitation, Earthquake response, Torsional response, Spectrum analysis, Buildings

A computational scheme is presented to construct torsional spectra due to the rotational component of seismic ground motions. The rotational component of ground motion is estimated from the measured earthquake acceleration records. In contrast to previous studies, no differentiation of acceleration records is involved in the present scheme. The torsional spectrum of the 1940 El Centro earthquake is computed and compared with previous results. An average and a mean plus one standard deviation torsional spectrum is presented for design purposes. These spectra are results based on four historical records (1934 El Centro, 1940 El Centro, 1949 Olympia and 1952 Taft) normalized to the 1940 El Centro intensity.

78-1745

High Earthquake Risk Buildings in New Zealand

R. Shepherd
Univ. of Auckland, New Zealand,
Intl. J. Earthquake Engr. Struc. Dynam., 6 (4), pp 383-395 (July/Aug 1978) 9 figs, 2 tables, 8 refs

Key Words: Seismic design, Buildings

Many existing buildings in seismically active areas were constructed prior to the acceptance of any design criteria specifically intended to produce earthquake resistance in the structure. Although such buildings are typically fifty or more years old they still constitute a large proportion of occupied domestic and commercial accommodation. Since almost all these structures comprise greater hazards than more recent constructions they are referred to as High Earthquake Risk buildings. The problems of identification, assessment and alleviation of the deficiencies have received increasing attention in recent years. In this paper some New Zealand experience is recounted.

78-1746

A Reconnaissance Report for the Romanian Earthquake of 4 March 1977

S.S. Tezcan, V. Yerlici, and H.T. Durgunoglu
Bogazici Univ., Istanbul, Turkey,
Intl. J. Earthquake Engr. Struc. Dynam., 6 (4), pp 397-421 (July/Aug 1978) 26 figs, 1 table, 15 refs

Key Words: Earthquake damage, Buildings

The engineering aspects of the 4 March 1977 Romanian earthquake are presented. They are based upon a field investigation conducted by the writers in Bucharest and in southern Romania in collaboration with members of the Building Research Institute of Romania, during the period 25-31 March 1977. This report covers general observations, data and evaluation on the character of the earthquake, structural damage inflicted by it, performance of different types of buildings during the earthquake and relief operations.

78-1747

A Model for Formulating Seismic Design Provisions

C. Culver
National Bureau of Standards, Washington, D.C.,
10 pp (June 1977)
PB-280 397/1GA

Key Words: Buildings, Earthquake resistant structures

The paper describes a program currently underway in the United States to develop improved seismic design provisions for buildings. Organization of the activity, the form of the provisions and the technical areas included are discussed. Important aspects of the provisions dealing with: design ground motion, structural design, architectural and mechanical-electrical design, and existing buildings are summarized.

SHOCK

(Also see Nos. 1705, 1725, 1726, 1727, 1728, 1797, 1854, 1855, 1881)

78-1748

Evaluation of the Shock Block Technique for Generating Underwater Plane Waves

A.L. Florence and C.M. Romander
Sri International, Menlo Park, CA., Rept. No. DNA-4447Z, AD-E300 169, 33 pp (Oct 1977)
AD-A053 419/8GA

Key Words: Underwater explosions, Shock wave propagation

Underwater Explosions Research Division has developed a shock block technique for generating underwater plane waves for the Defense Nuclear Agency. The technique was designed to produce a pulse that would simulate the pulse generated by an underwater nuclear explosion and was developed to improve the current method of loading submarine sections in which the energy source is concentrated as either a large sphere or a single line of explosive. This report discusses our work and recommends improvements. Examination of the experimental results revealed that the pulse generated by the equally spaced array of horizontal strands of Primacord explosive forming the shock block was of much shorter duration than predicted by superposition of the pulses from the individual strands. Instead of the required long rectangular pulse, the technique produces a short half-sine wave pulse. The work suggested the use of a helical coil of Primacord wrapped on a disposable cylindrical mandrel as an alternative to the straight strand of Primacord. The coil axis is horizontal and the pitch is the smallest that allows reliable detonation of the complete strand forming the helix without appreciable displacement.

78-1749

Duration of Nuclear Explosion Ground Motion

W.W. Hays, K.W. King, and R.B. Park
U.S. Geological Survey, Denver Federal Center, Denver, CO 80225, Bull. Seismol. Soc. Amer., 68 (4), pp 1133-1145 (Aug 1978) 15 figs, 29 refs

Key Words: Nuclear explosion effects, Ground motion

This paper evaluates the duration of strong ground shaking that results from nuclear explosions and identifies some of the problems associated with its determination. Knowledge of the duration of horizontal ground shaking is important out to the epicentral distances of about 44 km and 135 km, the approximate distances at which the ground shaking level falls to 0.01 g for nuclear explosions having yields of about 100 kt and 1,000 kt, respectively. Evaluation of the strong ground motions recorded from the event STRAIT (M_L = 5.6) on a linear array of five, broad-band velocity seismographs deployed in the distance range 3.2 to 19.5 km provides information about the characteristics of the duration of ground shaking.

78-1750

Mode and Bound Approximation Methods for Large Deflections of Dynamically Loaded Structures with Plastic and Viscoplastic Behavior

P.S. Symonds
Div. of Engrg., Brown Univ., Providence, RI, 16 pp (Apr 15, 1978)
AD-A054 277/9GA

Key Words: Structural response, Pulse excitation, Plastic properties, Viscoplastic properties

The research aimed at finding and developing methods for estimating the main features of response of engineering structures subjected to severe dynamic loading of pulse type, with emphasis put on methods valid both for large deflections and for structures of materials exhibiting strong strain rate sensitivity in the plastic range. Problem types of practical importance include explosive loading, either external due to military attack or internal for example due to disruptive accident in a pressure vessel or containment structure; various types of vehicular impact; wave impact on ship or offshore structures; and high energy rate forming. Preliminary applications have been made of the methods under investigation in the program presently being reviewed in all but the last of the above areas.

GENERAL WEAPON

(See No. 1807)

TRANSPORTATION

(See No. 1732)

PHENOMENOLOGY

DAMPING

(Also see Nos. 1700, 1770, 1836, 1837, 1838, 1839, 1856, 1891)

78-1751

An Experimental Study of the Steady-State Response of Oil-Film Dampers

R.K. Sharma and M. Botman

Pratt & Whitney Aircraft of Canada, Ltd., Longueuil, Quebec, Canada, J. Mech. Des., Trans. ASME, 100 (2), pp 216-221 (Apr 1978) 12 figs, 7 refs

Key Words: Fluid-film damping, Oil film bearings, Periodic response

Oil-film dampers are an integral feature of most high-speed, lightweight turbo engines, in which they are used to suppress undesirable shaft dynamic responses. They are generally located at the antifriction main bearings. An experimental study of the steady-state response of an oil-film damper at a main bearing was conducted on the high-speed rig developed for this purpose. The rig and some typical test results on a damper with a discrete number of oil-inlet ports were described in an earlier publication. In this paper, the experimental results are presented on dampers with different geometries and oil-supply arrangements. The results are presented in terms of transmissibility, deflection and damping coefficient plots. The response of the damper with radial springs to simulate gravity effects in a vertical rotor arrangement is compared to that without radial springs.

78-1752

Experimental and Analytical Investigation of Squeeze Film Bearing Damper Forces Induced by Offset Circular Whirl Orbits

P.N. Bansal and D.H. Hibner

Structures Technology Group, Commercial Products Div., Pratt & Whitney Aircraft Group, Div. of United Technologies Corp., East Hartford, CT, J. Mech. Des., Trans. ASME, 100 (3), pp 549-557 (July 1978) 10 figs, 19 refs

Key Words: Squeeze-film dampers, Hydrodynamic excitation, Whirling

A basic research program was conducted to investigate the hydrodynamic forces of a squeeze film bearing damper. These forces were induced by controlled offset circular whirl orbits of the damper journal. The orbits were mechanically produced by eccentric damper rings and cams in a specially designed, end sealed test rig. Aircraft engine damper geometry and operating conditions were simulated. The instantaneous circumferential pressure profiles, for specific orbits, were measured by eight high response pressure transducers. These test values are required to compare theory with test. Since the data reduction for offset orbits is extremely complicated, this simple method was found to be very useful in analyzing the test results. Test results for pressure profiles as well as damper forces were compared with theoretical predictions. The analysis is based on "long bearing" solution of Reynolds equation and includes the effect of inlet and cavitation pressures. For the cavitated oil film, inlet pressure was shown to have important effect on damper forces.

78-1753

Analysis and Experimental Investigation of the Stability of Intershaft Squeeze Film Dampers - Part 2: Control of Instability

D.H. Hibner, P.N. Bansal, and D.F. Buono

Pratt and Whitney Aircraft, East Hartford, CT, J. Mech. Des., Trans. ASME, 100 (3), pp 558-562 (July 1978) 8 figs, 5 refs

Key Words: Stability, Squeeze-film dampers, Rotor-bearing systems

A comprehensive stability analysis is used to study the stability of the test rig which incorporates a modified intershaft bearing support. The analysis is applicable to large multi-mass, rotor-bearing systems and includes the effects of gyroscopic moments, shear deformation, bearing support flexibility, and damping. The results of the stability analysis are presented in the form of system stability maps which clearly indicate the effectiveness of the modification in improving the instability onset speed of the system. Also presented are the results of an experimental investigation which substantiate the analytical predictions.

78-1754

Squeeze Film Damper Characteristics for Gas Turbine Engines

R.A. Marmol and J.M. Vance

Government Products Div., Pratt and Whitney Aircraft Group, West Palm Beach, FL, J. Mech. Des., Trans. ASME, 100 (1), pp 139-146 (Jan 1978) 12 figs, 9 refs

Key Words: Squeeze-film dampers, Gas turbine engines, Mathematical models

A mathematical model for squeeze film dampers is developed, and the solution results are compared with data from four different test rigs. A special feature of the analysis is the treatment of several different types of end seals and inlets, with inlet feedback included. A finite difference method is used to solve the Reynolds equation, with a banded matrix inversion routine. The test data are taken from a new high-speed free-rotor rig, and from three previously tested controlled-orbit rigs.

78-1755

The Dynamic Characteristics of O-Rings

A.J. Smalley, M.S. Darlow, and R.K. Mehta

Mechanical Technology, Inc., Latham, NY, J. Mech. Des., Trans. ASME, 100 (1), pp 132-138 (Jan 1978) 12 figs, 6 refs

Key Words: Elastomeric dampers, Experimental data

Stiffness and damping characteristics for O-rings are presented and discussed. These characteristics have been determined as a function of frequency and the effect of the following test parameters have been investigated: O-ring material, O-ring cross-section diameter, temperature, amplitude, squeeze, stretch, and groove width. The base excitation, resonant mass method, has been used in conjunction with a computerized system for data acquisition and reduction. Generally consistent data has been obtained and the trends resulting from the parameter changes are, qualitatively, as would be expected.

78-1756

Extinction of Predominantly Subharmonic Oscillations in a Non Linear Dynamic Damper with Two Degrees of Freedom

R. Riganti

Inst. for Rational Mechanics, Polytecnic of Turin, Italy, Mech. Res. Comm., 5 (3), pp 113-119 (1978) 5 figs, 10 refs

Key Words: Nonlinear damping

Following previous studies on the subharmonic response of forced non linear systems, the steady-state, 1/3 subharmonic oscillations of a dynamic damper with two degrees of freedom, sinusoidal forcing function and viscous dampings are examined. From the analysis, easy theoretical conditions are derived, regarding the limiting values of the various parameters needed to destroy the predominantly subharmonic component in the periodical oscillations of the damper. The results deduced from the proposed conditions are compared with the ones obtained by numerical integration of the equations of motion of the dynamical system.

78-1757

Damping Materials Provide Low-Cost Solutions to Vibration Problems

S/V, Sound Vib., 12 (8), pp 4-7 (Aug 1978)

Key Words: Material damping, Aircraft engines, Airframes

The use of damping materials in aircraft engines and airframes to prevent cracking as a result of vibration is described.

78-1758

Design Evaluation of Layered Viscoelastic Damping Treatments

A.D. Nashif and W.G. Halvorsen

Anatrol Corp., Cincinnati, OH, S/V, Sound Vib., 12 (7), pp 12-15 (July 1978) 9 figs, 3 refs

Key Words: Viscoelastic damping, Beams, Structural elements

Design procedures are presented for predicting the performance of viscoelastic vibration damping treatments for application to structures. The results presented are based primarily on the application of damping treatments to simple beams. However, similar procedures have been developed for more complicated systems such as plates and stiffened structures. Correlation between the predicted and measured results using the approach described in the article is very good.

FATIGUE

78-1759

Fatigue Life Prediction of Complex Structures

B.N. Leis

Battelle Columbus Labs., Columbus, OH, J. Mech. Des., Trans. ASME, 100 (1), pp 2-9 (Jan 1978) 4 figs, 52 refs

Key Words: Fatigue life

Because of the complex nature of the fatigue process, it is only recently that reasonably effective analysis procedures for predicting finite-fatigue life for simple notched coupons have evolved. One of the more vexing problems in adapting these procedures to making life predictions for complex components and structures is that of the multiplicity of crack initiation sites and mechanisms which determine the fatigue life of such structures. It has been observed that which of the many potential initiation sites and mechanisms controls failure depends on the service environment and the magnitude and character of the service loading. The present paper critically examines available technology for fatigue analysis of complex structures in which the multiplicity of initiation sites and mechanisms control the structure's life.

78-1760

Dynamic Severity Criterion for Designing Against High Cycle Fatigue

G.S.A. Shawki

Faculty of Engrg., Cairo Univ., Cairo, Egypt, J. Mech. Des., Trans. ASME, 100 (1), pp 10-15 (Jan 1978) 12 figs, 33 refs

Key Words: Fatigue (materials)

A novel approach to the interpretation of material behavior under cyclic loading is presented. In this approach a nondimensional criterion, featuring the dynamic severity of applied load, is put forward with a view to the provision of simple though confident assessment of component performance under dynamic load. The fatigue diagram based on the proposed criterion displays significant merits over previous diagrams, the presented approach thus providing an effective tool for designing against high cycle fatigue with due consideration to maximum utilization of material.

FLUID

(Also see Nos. 1795, 1810, 1811, 1813, 1875)

78-1761

Aeroelastic Instability of Rectangular Cylinders in a Heaving Mode

K. Washizu, A. Ohya, Y. Otsuki, and K. Fujii

Dept. of Aeronautics, Univ. of Tokyo, Tokyo, Japan, J. Sound Vib., 59 (2), pp 195-210 (July 22, 1978) 16 figs, 11 refs

Key Words: Cylinders, Rectangular bodies, Aeroelasticity, Fluid-induced excitation

This paper deals with wind tunnel experiments on the aeroelastic instability in a heaving mode of two-dimensional rectangular cylinders in a uniform two-dimensional flow. Both the free oscillation method and the forced oscillation method are employed for the experiments. Emphasis is placed on finding the effect of the ratio c/d, which is the ratio of the lengths of the sides of the rectangle, to the aeroelastic instability phenomena in the vicinity of the resonance speed. Emphasis is also placed on finding possible limitations in the application of the quasi-steady aerodynamic theory to the analysis of the aeroelastic characteristics.

78-1762

Extremes of Morison-Type Wave Loading on a Single Pile

G. Moe and S.H. Crandall

Massachusetts Inst. of Tech., Cambridge, MA, J. Mech. Des., Trans. ASME, 100 (1), pp 100-104 (Jan 1978) 3 figs, 9 refs

Key Words: Offshore structures, Piles, Water waves, Fluid-induced excitation

A statistical estimate of the extreme wave force perunit length acting on a section of a fixed cylindrical pile in a random sea-state is derived. The random motion of the sea is described by a spectrum of wave heights in conjunction with linear wave theory. The wave force is assumed to depend linearly on the water particle acceleration and nonlinearly on the water velocity according to the Morison formula. The interaction of the velocity and acceleration contributions and the contribution of a small steady current are accounted for by an asymptotic approximation valid for large forces. The expected rate of occurrences of extremes based on a simple peak definition agrees satisfactorily with a more elaborate result based on a true maximum definition. The formulas derived here provide a basis for a design-force procedure which could provide an improvement over the design-wave procedure commonly used for the analysis of offshore structures.

SOIL

78-1763

The Spring Method for Embedded Foundations

E. Kausel, R.V. Whitman, J.P. Morray, and F. Elsabee

Stone and Webster Engrg. Corp., 245 Summer St., Boston, MA 02107, Nucl. Engr. Des., 48 (2/3), pp 377-392 (Aug 1978) 16 figs, 34 refs

Key Words: Interaction: soil-structure, Spring method

The paper presents simplified rules to account for embedment and soil layering in the soil-structure interaction problem, to be used in dynamic analyses. The relationship between the spring method, and a direct solution (in which both soil and structure are modeled with finite elements and linear members) is presented. It is shown that for consistency of the results obtained with the two solution methods, the spring method should be performed in three steps.

78-1764

Some Aspects of the Ground Vibration Problem

T.G. Gutowski, L.E. Wittig, and C.L. Dym

Noise Control Engr., 10 (3), pp 94-100 (May-June 1978) 8 figs, 24 refs

Key Words: Ground vibration

The topic of ground vibration involves many disciplines; pertinent work has been done in the areas of seismology, civil engineering, acoustics, noise control, and biomechanics, to mention a few. The purpose of this paper is to draw together some of these results and to show their applicability to solving ground vibration problems.

78-1765
Soil-Structure Interaction. A Background Discussion for the Swedish Council for Building Research

S. Hansbo and G. Karrholm

Swedish Council for Building Res., Stockholm, Sweden, Rept. No. ISBN-91-540-2719-5; D10:1977, 30 pp (1977)

PB-280 181/9GA

Key Words: Interaction: soil-structure, Reviews

The report investigates damages caused by improper consideration of soil-structure interaction, mechanical properties of soils, mechanical properties of superstructures, computation models, and surveys of research problems.

VISCOELASTIC
(See Nos. 1758, 1796)

EXPERIMENTATION

BALANCING
(Also see No. 1769)

78-1766
Turbine Engine Rotor Dynamic Evaluation. Volume II. Engine and Test Rig Balancing

J. Davis, J. Tessarzik, and R.A. Rio

Mechanical Technology, Inc., Latham, NY, Rept. No. MTI-76TR41-VOL-2, AFAPL-TR-76-81-VOL-2, 52 pp (Jan 1978)

AD-A054 533/5GA

Key Words: Balancing techniques, Turbine engines

Balancing demonstrations were performed to show the applicability of combining dynamic characteristics and advanced balancing techniques to effectively reduce the vibration of production type machinery. Trim balancing procedures were performed on the TF30, TF41 and F100 jet engines which are currently in use on military aircraft. A very sensitive high-speed experimental test apparatus called the 'Rub Rig' was also used to show the benefits of multiplane-multispeed balancing using influence coefficients.

DIAGNOSTICS

78-1767
Detection of Rolling Element Bearing Damage by Statistical Vibration Analysis

D. Dyer and R.M. Stewart

Mech. Engrg. Labs., G.E.C. Power Engrg., Whetstone, Leicester, UK, J. Mech. Des., Trans. ASME, 100 (2), pp 229-235 (Apr 1978) 9 figs, 16 refs

Key Words: Housings, Bearings, Diagnostic techniques

A new method is presented for predicting rolling element bearing condition from measurements of bearing housing vibration. This method is based on a statistical parameter Kurtosis, that remains constant for an undamaged bearing irrespective of load and speed, yet changes with damage. The extent of damage can be assessed from the distribution of this statistical parameter in selected frequency ranges. An assessment of bearing condition can thus be made with minimum recourse to historical information. Most other damage detection techniques rely heavily on the trend analysis of data and so this new method may prove to be a significant advance in bearing fault detection technology, at least when viewed within the original objective to provide a simple and cheap technique. As with most other simple detection techniques, the precise nature of the fault cannot be defined and for such information it is necessary to use the more sophisticated diagnostic methods.

78-1768
An Evaluation Technique for Determining the Cost Effectiveness of Condition Monitoring Systems

P.T. George and A.T. Parker

Pratt & Whitney Aircraft Group, East Hartford, CT, ASME Paper No. 78-GT-166

Key Words: Diagnostic techniques

A technique for analyzing the cost-effectiveness of condition monitoring systems has been developed both to provide a quantitative assessment of the value of condition monitoring and to guide the selection of items to be monitored by the system. The technique uses historical data combined with catalog cost estimating to estimate both the life cycle cost of the condition monitoring system and the potential cost savings offered by the system for commercial engines. The results are obtained in a form that can be easily converted to any of the primary cost-effectiveness parameters in current use by industry.

78-1769

Turbine Engine Automated Trim Balancing and Vibration Diagnostics

R. McTasney, R.A. Rio, and W.A. Troha

Oklahoma City Air Logistics Center, Oklahoma City, OK, ASME Paper No. 78-GT-129

Key Words: Turbine engines, Balancing techniques, Diagnostic techniques

After turbine engine is overhauled at Oklahoma City Air Logistics Center (OC-ALC) or at San Antonio Air Logistic Center (SA-ALC), it is run in the test cell before shipment. While in the test cell, final adjustments are made to the engine. One of these adjustments is the dynamic vibration balance of the engine. This adjustment is referred to as a trim balance. The current trim balance procedures in use at OC-ALC require the engine to be in the test cell from 4 to 6 hours.

78-1770

Signature Analysis of Acoustic Emissions From Composites. Final Report. 1 Oct 1975 - 30 Mar 1978

E.G. Henneke, II

Dept. of Engrg. Science and Mech., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA., Rept. No. NASA-CR-145373, 79 pp (May 19, 1978) N78-23148

Key Words: Acoustic signatures, Fracture properties, Composite materials

Acoustic emission data were obtained from a series of tensile tests on specially designed graphite-epoxy unidirectional laminates. The design was such that the specimens would preferentially fail first by fiber breakage and later by matrix splitting. The AE signals for each of these events was analyzed and some typical results are reported. Patterns characteristic of each failure mechanism were noted for both the time signatures and the corresponding frequency spectra.

EQUIPMENT

(See Nos. 1724, 1837)

INSTRUMENTATION

(Also see No. 1715)

78-1771

Frequency Spectrum Analyzer

M.J. Post, R.E. Cupp, and R.L. Schwiesow

Wave Propagation Lab., National Oceanic and Atmospheric Adminstration, Boulder, CO, Rept. No. NOAA-TR-ERL-392, WPL-51, 8 pp (Oct 1976) PB-280 941/6GA

Key Words: Frequency analyzers

The report describes an electronic apparatus that analyzes Doppler returns from an infrared lidar system. By processing each spectral frequency channel with a 100 percent duty cycle rather than with a swept filter analyzer, considerably better S/N is obtained.

78-1772

Industrial Sound Level Meter Environmental Testing

R.J. Koshut

Testing and Certification Branch, National Inst. for Occupational Safety and Health, Morgantown, WV, Rept. No. NIOSH/TC/P-015, 35 pp (Apr 1978) PB-280 028/2GA

Key Words: Sound level meters, Environmental effects

This test procedure checks the effect on an industrial sound level meter when it is subjected to environmental conditions of temperature and humidity. Included is a list of equipment needed to perform the test and the configuration in which the equipment is to be used.

TECHNIQUES

(See Nos. 1713, 1715, 1736)

COMPONENTS

ABSORBERS

78-1773

Physical and Acoustical Properties of Urethane Foams

E. O'Keefe

Specialty Composites Corp., Newark, DE, S/V, Sound Vib., 12 (7), pp 16-21 (July 1978) 7 figs, 3 tables, 12 refs

Key Words: Foams, Acoustic properties, Vibration dampers, Acoustic absorption, Noise barriers

The basic processes governing the manufacturing of acoustical foams, as well as the physical properties which affect their use as an acoustic absorber, barrier, or vibration damper are described. Some of the properties which determine the acoustical properties are the flow resistance, thickness, type of facing, stiffness, and even temperature. The relevance of different methods for determining acoustical performance are discussed, and methods are recommended for specifying some of the important acoustic parameters of acoustical foams.

SHAFTS

(See Nos. 1834, 1892)

BEAMS, STRINGS, RODS, BARS

(Also see Nos. 1723, 1789)

78-1774

The Dynamics and Control of Large Flexible Space Structures. Part A: Discrete Model and Modal Control

P.M. Bainum and R. Sellappan
Dept. of Mech. Engrg., Howard Univ., Washington, D.C., Rept. No. NASA-CR-156975, 59 pp (May 1978)
N78-23139

Key Words: Spacecraft, Beams, Mathematical models, Lumped parameter methods, Modal control technique

Attitude control techniques for the pointing and stabilization of very large, inherently flexible spacecraft systems were investigated. The attitude dynamics and control of a long, homogeneous flexible beam whose center of mass is assumed to follow a circular orbit was analyzed. First order effects of gravity gradient were included. A mathematical model which describes the system rotations and deflections within the orbital plane was developed by treating the beam as a number of discretized mass particles connected by massless, elastic structural elements. The uncontrolled dynamics of the system are simulated and, in addition, the effects of the control devices were considered. The concept of distributed modal control, which provides a means for controlling a system mode independently of all other modes, was examined. The effect of varying the number of modes in the model as well as the number and location of the control devices were also considered.

78-1775

The Dynamics and Control of Large Flexible Space Structures. Part B: Development of Continuum Model and Computer Simulation

P.M. Bainum, V.K. Kumar, and P.K. James
Dept. of Mech. Engrg., Howard Univ., Washington, D.C., Rept. No. NASA-CR-156976, 116 pp (May 1978)
N78-23140

Key Words: Spacecraft, Beams, Mathematical models, Computerized simulation, Equations of motion

The equations of motion of an arbitrary flexible body in orbit were derived. The model includes the effects of gravity with all its higher harmonics. As a specific example, the motion of a long, slender, uniform beam in circular orbit was modeled. The example considers both the inplane and three dimensional motion of the beam in orbit. In the case of planar motion with only flexible vibrations, the pitch motion is not influenced by the elastic motion of the beam. For large values of the square of the ratio of the structural modal frequency to the orbital angular rate the elastic motion was decoupled from the pitch motion. However, for small values of the ratio and small amplitude pitch motion, the elastic motion was governed by a Hill's 3 term equation. Numerical simulation of the equation indicates the possibilities of instability for very low values of the square of the ratio of the modal frequency to the orbit angular rate. Also numerical simulations of the first order nonlinear equations of motion for a long flexible beam in orbit were performed. The effect of varying the initial conditions and the number of modes was demonstrated.

78-1776

On the Multiplicity of Solutions of the Inverse Problem for a Vibrating Beam

V. Barcilon
Dept. of Geophysical Sciences, Chicago, Univ., IL, 19 pp (Apr 1978)
AD-A054 248/0GA

Key Words: Beams, Spectrum analysis

The 2 to the N-1 power fold multiplicity of solutions found by Boley and Golub in their study of the inverse problem for N X N symmetric, pentadiagonal matrices contrasts with the unicity of the solution of the inverse problem for an inhomogeneous, discrete beam.

78-1777

Minimum Mass Structures with Specified Natural Frequencies

A. Miele
Aero-Astronautics Group, Rice Univ., Houston, TX, Rept. No. AAM-WP-1, AFOSR-TR-78-0751, 27 pp (1976)
AD-A053 727/4GA

Key Words: Cantilever beams, Natural frequencies, Minimum weight design

The problem of the axial vibration of a cantilever beam is investigated numerically. The mass distribution that minimizes the total mass for a given fundamental frequency constraint is determined using both the sequential ordinary gradient-restoration algorithm (SOGRA) and an ad hoc modification of the modified quasilinearization algorithm (MQA).

78-1778

Numerical Determination of Minimum Mass Structures with Specified Natural Frequencies

A. Miele, A. Mangiavacchi, B.P. Mohanty, and A.K. Wu
Aero-Astronautics Group, Rice Univ., Houston, TX, Rept. No. AAR-138, AFOSR-TR-78-0723, 64 pp (1977)
AD-A053 725/8GA

Key Words: Cantilever beams, Natural frequencies, Minimum weight design

The problem of the axial vibration of a cantilever beam is investigated both analytically and numerically. The mass distribution that minimizes the total mass for a given value of the frequency parameter beta is determined using both the sequential ordinary gradient-restoration algorithm (SOGRA) and the modified quasilinearization algorithm (MQA). Concerning the minimum value of the mass, SOGRA leads to a solution precise to at least 4 significant digits and MQA leads to a solution precise to at least 6 significant digits. Comparison of the optimal beam (a variable-section beam) with a reference beam (a constant-section beam) shows that the weight reduction depends strongly on the frequency parameter beta.

78-1779

Some Qualitative Considerations on the Numerical Determination of Minimum Mass Structures with Specified Natural Frequencies

A. Mangiavacchi and A. Miele
Aero-Astronautics Group., Rice Univ., Houston, TX, Rept. No. AAM-WP-2, AFOSR-TR-78-0724, 17 pp (1977)
AD-A053 726/6GA

Key Words: Cantilever beams, Natural frequencies, Minimum weight design

The problem of the axial vibration of a cantilever beam is investigated analytically. The range of values of the frequency parameter having technical interest is determined.

78-1780

Traveling Loads on the Timoshenko Beam

P.J. Torvik
Air Force Inst. of Tech., Wright-Patterson AFB, OH, Rept. No. AFIT-TR-78-2, 42 pp (Apr 1978)
AD-A054 628/3GA

Key Words: Beams, Timoshenko theory, Moving loads, Critical speeds

A transverse force traveling along an infinite string or a beam at critical values of constant velocity generates unbounded amplitudes, in the absence of dissipation. This resonance is analogous to the unbounded amplitudes generated by a stationary force oscillating at one of the natural frequencies. The response of a finite elementary beam to a moving force of constant amplitude can be determined in terms of the eigenfunctions of the beam. Modification of elementary beam theory to take into account the effects of rotatory inertia and shear leads to the Timoshenko beam theory, from which a new set of eigenvalues and eigenfunctions can be determined. These eigenfunctions can be shown to have an orthogonality relationship which, although unusual, permits the solution of initial value and non-homogeneous problems. The procedure for solving such problems is given, and applied to the problem of a traveling load on a finite Timoshenko beam with arbitrary end conditions. Results are obtained for the case of pinned ends, and compared with those from elementary theory.

78-1781

Vibration of an Elastic Beam Subjected to Discrete Moving Loads

M. Kurihara and T. Shimogo
Faculty of Engrg., Keio Univ., Yokohama, Japan, J. Mech. Des., Trans. ASME, 100 (3), pp 514-519 (July 1978) 6 figs, 6 refs

Key Words: Beams, Moving loads, Random excitation, Poisson's ratio, Time-dependent excitation, Spectral energy distribution techniques

In this paper, vibration problems of a simply-supported elastic beam subjected to randomly spaced moving loads with a uniform speed are treated under the assumption that the input load sequence is a Poisson process. In the case in which the inertial effect of moving loads in neglected,

the time history, the power spectral density, and the various moments of the response are examined and the effects of the speed of moving loads upon the beam are made clear.

78-1782
Stability of a Simply-Supported Beam Subjected to Randomly Spaced Moving Loads

M. Kurihara and T. Shimogo
Faculty of Engrg., Keio Univ., Yokohama, Japan,
J. Mech. Des., Trans. ASME, 100 (3), pp 507-513 (July 1978) 7 figs, 7 refs

Key Words: Beams, Moving loads, Random excitation, Poisson's ratio, Inertial forces, Coriolis forces

In this paper, vibration problems of a simply-supported elastic beam subjected to randomly spaced moving loads with a uniform speed are treated under the assumption that the input load sequence is a Poisson process. In the case in which the inertial effect of moving loads is taken into account, the stability problem relating to the speed and the mass of loads is dealt with, considering the inertia force, the centrifugal force, and the Coriolis force of the moving loads. As an analytical result a stability chart of the mean-squared deflection was obtained for the moving speed and the moving masses.

78-1783
The Vibration Characteristics of a Beam with an Axial Force

R.E.D. Bishop and W.G. Price
Dept. of Mech. Engrg., Univ. College London, London WC1E 7JE, UK,
J. Sound Vib., 59 (2), pp 237-244 (July 22, 1978) 2 figs, 4 refs

Key Words: Beams, Equations of motion, Timoshenko theory

Equations of motion are found for a non-uniform damped Timsohenko beam with a distributed axial force. Principal modes may be extracted by numerical means when the boundary conditions are specified, and the appropriate orthogonality conditions are given. The theory of linear forced vibration can thus be derived. It is an implicit requirement that all axial forces are conservative.

78-1784
Vibrations of Continuous Timoshenko Beams on Winkler-Pasternak Foundations

T.M. Wang and L.W. Gagnon
Dept. of Civil Engrg., Univ. of New Hampshire, Durham, NH 03824,
J. Sound Vib., 59 (2), pp 211-220 (July 22, 1978) 7 figs, 7 refs

Key Words: Beams, Timoshenko theory, Rotatory inertia effects, Transverse shear deformation effects

The dynamic analysis of continuous Timoshenko beams on Winkler-Pasternak foundations by means of the general dynamic slope-deflection equations is presented. A three-span continuous beam on a Winkler-Pasternak foundation subjected to free and forced vibrations is used to illustrate the application of the proposed method and to show the effects of rotary inertia, transverse-shear deformation and foundation constants on the beam.

78-1785
Parametric Study of Free Vibration of Sagged Cables

M.L. Gambhir and B. deV. Batchelor
Queen's Univ. at Kingston, Ontario, Canada,
Computers Struc., 8 (5), pp 641-648 (May 1978) 8 figs, 10 refs

Key Words: Cables (ropes), Natural frequencies, Mode shapes, Finite element technique, Parametric excitation

The finite element method is applied to the study of natural frequencies and modes of vibration of sagged cables. Extensional characteristics of the element are fully considered. The method is applied to a numerical example taken from the literature and which has previously been analyzed by classical and other methods. The results obtained by the use of a straight element are compared with those obtained by the use of curved elements. Finally, a parametric study is conducted to determine the influence of various parameters on the spectrum of natural frequencies of a sagged cable and appropriate nondimensional curves are presented. These non-dimensional curves give an insight into the general characteristics of the sagged cable, and can be used to predict in-plane natural frequencies over a wide range of sag/span ratio.

BEARINGS
(Also see Nos. 1751, 1767)

78-1786
Elastomeric Bearings Don't Slide or Roll

J.R. Potter
Lord Kinematics, Lord Corp., Erie, PA,
Power Transm. Des., 20 (7), pp 38-40 (July 1978) 11 figs

Key Words: Elastomeric bearings

Elastomeric bearings serve well in oscillatory or reciprocating motion applications. They require no lubrication and the functions of several bearing types can often be combined in one bearing, thus simplifying a design. This article presents the various types of elastomeric bearings and their operating principles.

78-1787

Single-Row Sphericals: Less Bearing, Longer Life

J. Rader

Bearing Div., McGill Mfg. Co., Valparaiso, IN, Power Transm. Des., 20 (7), pp 35-37 (July 1978) 6 figs

Key Words: Roller bearings

Specialists in bearing technology have long recognized the performance advantages of single-row spherical roller bearings, which accommodate large shaft deflection and misalignment to ± 3°. The article discusses an application of single-row sphericals and two applications where one row was better than two.

BLADES

(Also see No. 1895)

78-1788

Vibration Characteristics of Hollow Symmetrical Blades Based on Thin Shell Theory

A.M. Al Jumaily and L.L. Faulkner

Dept. of Mech. Engrg., Ohio State Univ., Columbus, OH, J. Mech. Des., Trans. ASME, 100 (1), pp 183-187 (Jan 1978) 5 figs, 4 tables, 9 refs

Key Words: Turbomachinery blades, Blades, Shells, Natural frequencies

This paper presents the results of investigating the vibrational characteristics of a hollow symmetrical blade based on thin shell theory which allows closed function representation of vibrational characteristics which are inaccessible using beam theory. A modified shell theory is presented and used for the analysis. This technique is used to express the results in a continuous function analytical formation. The method presented is clearly for long hollow blades and does not require the computer storage of numerical methods. Comparison is made between the present technique, the beam theory, and experimental data for two laboratory models. The formulation can be extended to most types of blades and still retain the functional representation.

78-1789

Comparison of Some Optimal Control Methods for the Design of Turbine Blades

B.M.E. de Silva and G.N.C. Grant

Aircraft Aerodynamics Branch, Aerodynamics Div., Ames Res. Center, NASA, Moffett Field, CA, J. Mech. Des., Trans. ASME, 100 (1), pp 173-182 (Jan 1978) 2 figs, 3 tables, 48 refs

Key Words: Turbine blades, Structural synthesis, Optimization, Numerical methods, Timoshenko theory

This paper attempts a comparative study of some numerical methods for the optimal control design of turbine blades whose vibration characteristics are approximated by Timoshenko beam idealizations with shear and incorporating simple boundary conditions. The blade was synthesized using the following methods: conjugate gradient minimization of the system Hamiltonian in function space incorporating penalty function transformations, projection operator methods in a function space which includes the frequencies of vibration and the control function, ϵ-technique penalty function transformation resulting in a highly nonlinear programming problem, finite difference discretization of the state equations again resulting in a nonlinear program, second variation methods with complex state differential equations to include damping effects resulting in systems of inhomogeneous matrix Riccatti equations some of which are stiff, and quasi-linear methods based on iterative linearization of the state and adjoint equation. The paper includes a discussion of some substantial computational difficulties encountered in the implementation of these techniques together with a resume of work presently in progress using a differential dynamic programming approach.

78-1790

Experimental Study on Blade Bending Vibration

T. Matsuura

Dept. of Engrg., Cambridge Univ., UK, Rept. No. CUED/A-Turbo/TR-88; ISSN-0309-6521, 32 pp (1977)

N78-23090

Key Words: Compressor blades, Flexural vibration, Vibration prediction, Experimental data

Experiments were performed on the forced vibration of cascade blades due to the upstream periodic wakes. The resonance vibration amplitude and phase of the 1st bending mode were measured in a compressor rotor with the h/t ratio of 0.4. Smith's unsteady lift coefficients were used, and the mechanical damping of the blade was introduced to predict the resonance amplitude and phase. Reasonable agreement was seen between the measured results and the prediction.

78-1791

Aerodynamic Phenomena in an Oscillating Transonic MCA Airfoil Cascade Including Loading Effects

S. Fleeter and R.E. Riffel

Detroit Diesel Allison, Indianapolis, IN, In: AGARD Unsteady Aerodyn., 16 pp (Feb 1978)
N78-22066

Key Words: Fan blades, Aerodynamic response

The steady, quasi-steady, and unsteady aerodynamics were determined for a multiple circular arc (MCA) airfoil cascade which modeled the tip section of an advanced design fan blade. The steady airfoil surface aerodynamic performance of the cascade was measured at two levels of aerodynamic loading and correlated with the predictions from a time-marching, steady, transonic flow analysis. The chordwise distribution of the quasi-static unsteady pressure coefficient for a 0 deg interblade phase angle was determined and correlated with two appropriate predictions: one based on the steady transonic analysis and the other on steady inviscid supersonic flat plate theory. Finally, the MCA cascade was harmonically oscillated in the torsional mode at a reduced frequency value of 0.14. The fundamental unsteady aerodynamic data was obtained at a Mach number equal to 1.55 over a range of interblade phase angles for two values of the cascade static pressure ratio. Results were correlated with the predictions from state-of-the-art unsteady flat plate cascade analyses.

78-1792

Dynamic Analysis of an Assembly of Shrouded Blades Using Component Modes

A.V. Srinivasan, S.R. Lionberger, and K.W. Brown

Commercial Products Div., Pratt & Whitney Aircraft, United Technologies Corp., East Hartford, CT, J. Mech. Des., Trans. ASME, 100 (3), pp 520-527 (July 1978) 11 figs, 3 tables, 9 refs

Key Words: Shrouds, Fan blades, Component mode synthesis, Vibration response

The problem of vibratory behavior of an assembly of shrouded fan blades is examined. The point of view that forms the basis for the analysis is that the vibration characteristics of an assembly of blades can be predicted from a knowledge of vibration characteristics of its components. Clearly, linear behavior is assumed. A viscous type of damping mechanism is included to account for any energy dissipation due to vibratory rubbing action at shroud interfaces. As the component modes are computed with a single blade and shroud modeled with plate elements, the extent of chordwise motion in different modes is examined. Numerical results of an application of the analysis to a typical fan design are included.

78-1793

Synthesis of Blade Flutter Vibratory Patterns Using Stationary Transducers

A. Kurkov and J. Dicus

Lewis Res. Center, NASA, Cleveland, OH, ASME Paper No. 78-GT-160

Key Words: Blades, Flutter

Flutter frequency was determined and rotor vibratory amplitude and phase distributions during flutter were reconstructed from stationary aerodynamic type measurements. A previously reported optical method for measuring blade-tip displacements during flutter was extended by means of digital analysis. Displacement amplitudes and phase angles were determined based on this method. For selected blades, spectral results were also obtained from strain gage measurements. The results from these three types of measurement were compared and critically evaluated.

78-1794

Vibrations of Cambered Helicoidal Fan Blades

K.P. Walker

Pratt & Whitney Aircraft, East Hartford, CT 06108, J. Sound Vib., 59 (1), pp 35-57 (July 8, 1978) 9 figs, 12 tables, 30 refs

Key Words: Fans, Blades, Shells, Natural frequencies, Mode shapes, Transverse shear deformation effects, Rotatory inertia effects

A conforming finite shell element suitable for the analysis of curved twisted fan blades is developed and applied to a number of fan blade models. The element is assumed to be a doubly curved right helicoidal shell, in which the curvature is shallow with respect to the twisted base plane defining the helicoid. Element stiffness and mass formulations are based on Mindlin's theory and include the effects of transverse shear and rotary inertia. The thick shell element has 64 generalized co-ordinates, and by deleting transverse shear effects, a thin shell version of the element having 40 generalized co-ordinates is obtained. The thin shell element is used to predict the natural frequencies and mode shapes of a number of fabricated fan blade structures and the results are correlated with experiment.

CONTROLS

78-1795

An Analysis of the Three-Way Underlapped Hydraulic Spool Servovalve

C.K. Taft and J.P. Twill

Dept. of Mech. Engrg., Univ. of New Hampshire, Durham, NH, J. Dyn. Syst., Meas. and Control, Trans. ASME, 100 (2), pp 117-123 (June 1978) 11 figs, 11 refs

Key Words: Hydraulic servomechanisms, Valves, Fluid-induced excitation, Mathematical models

A flow model of a three-way underlapped hydraulic servovalve is presented and used to derive a mathematical description of the flow momentum forces acting on the valve spool. The effect of these forces on valve performance is investigated by examining both the linearized system differential equations and digital computer solutions of the system nonlinear differential equations, and by experimental measurements. A three-dimensional phase space is used to display computer simulation results. Because of the oscillatory nature of system response, projections on a plane illustrate system dynamic response forms. The effects of system parameters on system stability are discussed.

CYLINDERS

78-1796

Dynamic Response of a Geometrically Nonlinear Elastic/Viscoelastic Cylinder

A.J.K. Neighbors

Ph.D. Thesis, The Univ. of Alabama, 173 pp (1977)
UM 7809870

Key Words: Cylinders, Composite structures, Viscoelastic-core containing media, Impact response

This work is concerned with the dynamic analysis of an infinitely long circular composite cylinder with a viscoelastic core and a thin elastic case. The thin elastic case serves as the principal load carrying structure while the viscoelastic core contributes mass and damping effects to the dynamic behavior. The cylinder is subjected to a uniform internal static pressure and an externally distributed impulse load.

78-1797

Shock Induced Structural Response

J.G. Gallo

Naval Postgraduate School, Monterey, CA, 58 pp (Mar 1978)
AD-A053 877/7GA

Key Words: Cylinders, Submerged structures, Interaction: structure-fluid, Shock response

An infinitely long, ring-stiffened, submerged, elastic cylinder having uniformly spaced elastic bulkheads is considered. Loading is applied by a plane acoustic shock wave with front parallel to the cylinder axis. Dynamic pressure in the fluid is resolved into a free-field incident part and a scattered part. Structural response and scattered pressure in the surrounding fluid are found using finite element modeling of structure and fluid. Introduction of Fourier series makes the fluid region mathematically two-dimensional. A radiation, or nonreflecting, condition at the outer boundary of the fluid region is shown to give good results. A parametric study is made of effects of shock pulse rise time and duration on structural response. Results are presented as combinations of shock pressure and submergence pressure just sufficient to induce structural failure.

DUCTS

(Also see Nos. 1735, 1767)

78-1798

High Frequency Sound Attenuation in Short Flow Ducts

J.W. Posey

Langley Res. Center, NASA, Langley Station, VA, Rept. No. NASA-TM-78708, 25 pp (May 1978)
N78-23876

Key Words: Ducts, Sound attenuation, High frequencies, Acoustic linings

A geometrical acoustics approach is proposed as a practical design tool for absorbent liners in such short flow ducts as may be found in turbofan engine nacelles. As an example, a detailed methodology is presented for three different types of sources in a parallel plate duct containing uniform ambient flow. A plane wave whose wavefronts are not normal to the duct walls, an arbitrarily located point source, and a spatially harmonic line source are each considered. Optimal wall admittance distributions are found, and it is shown how to estimate the insertion loss for any admittance distribution.

FRAMES, ARCHES

78-1799

Computer-Aided Optimum Seismic Design of Ductile Reinforced Concrete Moment-Resisting Frames

S.W. Zagajeski and V.V. Bertero

Earthquake Engrg. Res. Center, California Univ., Richmond, CA, Rept. No. UCB/EERC-77/16, 146 pp (Dec 1977)
PB-280 137/1GA

Key Words: Seismic design, Computer-aided techniques, Framed structures, Multistory buildings, Concrete

A computer-aided design procedure based on limit state design concepts is proposed for multistory reinforced concrete frames of buildings which are expected to experience severe earthquake ground shaking during their service life. In this procedure a structure is designed to meet various serviceability criteria under service loading conditions, damage limitations for abnormal environmental conditions, and safety requirements for extreme earthquake excitations. The design procedure, which makes use of computer optimization methods as well as static and dynamic elastic and nonlinear analysis procedures, consists in five basic steps which are grouped into a preliminary design phase and a final design phase.

78-1800

Spatial Symmetrical Vibrations and Stability of Circular Arches with Flexibly Supported Ends

Y. Wasserman
Dept. of Mech. Engrg., Ben Gurion Univ. of the Negev, Beersheva, Israel, J. Sound Vib., 59 (2), pp 181-194 (July 22, 1978) 7 figs, 3 tables, 10 refs

Key Words: Arches, Fundamental frequencies

In this work, exact formulae have been obtained for determining the lowest natural frequencies and critical loads of elastic circular arches with flexibly supported ends for symmetrical vibration in the direction perpendicular to the initial curvature of the arch. This investigation is concerned with three cases of load behavior during the process of deformation. The values of the frequencies and critical loads are shown to be dependent on the opening angle of the arch, on the stiffness of the flexibly supported ends and on the ratio of the flexural rigidity to the torsional rigidity of the arch cross-section.

GEARS

78-1801

Simulation of Resonances and Instability Conditions in Pinion-Gear Systems

M. Benton and A. Seireg
Dept. of Mech. Engrg., Univ. of Wisconsin, Madison, WI, J. Mech. Des., Trans. ASME, 100 (1), pp 26-32 (Jan 1978) 9 figs, 16 refs

Key Words: Gears, Periodic excitation, Periodic response, Stiffness, Computerized simulation

This paper describes a computer simulation procedure based on the phase-plane method for predicting the steady-state response, resonances and instabilities of pinion-gear systems subjected to sinusoidal excitation. An experimental technique is also presented which is capable of checking the accuracy of the simulation under different operating conditions. The experimental set-up which utilizes a shaker for producing variations of mesh stiffness without complete rotation of the gear pair provides a relatively simple and convenient means for investigating this class of problems.

78-1802

Stress Condition, Vibrational Exciting Force, and Contact Pattern of Helical Gears with Manufacturing and Alignment Error

A. Kubo
Kyoto Inst. of Tech., Matsugasaki, Kyoto, Japan, J. Mech. Des., Trans. ASME, 100 (1), pp 77-84 (Jan 1978) 9 figs, 12 refs

Key Words: Helical gears, Spur gears, Gears, Geometric imperfection effects

The general method for calculation of load sharing to every tooth pair in meshing, load distribution, and contact pattern on tooth flank of helical gears with manufacturing and alignment error is shown, for which some parts of tooth flanks on the geometrical line of contact can separate from each other due to the errors. For such gears, stiffness of meshing tooth pair, exciting force of gear vibration, and total composite error (single flank) under loaded condition is derived. Using this calculating method, tooth stiffness, vibration excitation, tooth fillet stress, and contact pattern are calculated for some helical and spur gears, and they are compared with measured results.

78-1803

Dynamic Tooth Loads and Stressing for High Contact Ratio Spur Gears

R.W. Cornell and W.W. Westervelt
Hamilton Standard, Div. of United Technologies Corp., Windsor Locks, CT, J. Mech. Des., Trans. ASME, 100 (1), pp 69-76 (Jan 1978) 13 figs, 2 tables, 10 refs

Key Words: Spur gears, Mathematical models, Computer programs

A time history, closed form solution is presented for a dynamic model of spur gear systems for all practical contact ratios. The analysis determines the dynamic response of the gear system and the associated tooth loads and stressing. The dynamic model is based on work done by Richardson and Howland and assumes the two gears act as a rigid inertia and the teeth act as a variable spring of a dynamic system excited by the meshing action of the teeth. Included in the analysis are the effects of the nonlinearity of the tooth pair stiffness during mesh, the tooth errors, and the tooth profile modifications. Besides reviewing the features, solution, and program of this analysis, preliminary results from applying the analysis are presented, which show that tooth profile modification, system inertia and damping, and system critical speeds can affect the dynamic gear tooth loads and stressing significantly.

78-1804

Design Synthesis of a Multi-Speed Machine Tool Gear Transmission Using Multiparameter Optimization

M.O.M. Osman, S. Sankar, and R.V. Dukkipati
Concordia Univ., Montreal, Quebec, Canada, J. Mech. Des., Trans. ASME, 100 (2), pp 303-310 (Apr 1978) 12 figs, 2 tables, 6 refs

Key Words: Power transmission systems, Gear drives, Machine tools, Structural synthesis, Optimization

This paper presents a novel method for the design synthesis of a multi-speed machine tool gear drive using a multiparameter optimization technique. The method eliminates any complex and tedious algebraic analysis normally required in gear train designs. It requires only the formulation of mesh and speed ratio equations from the geometrical arrangement of the gear drive and the selection of a suitable optimization criterion and constraints.

LINKAGES

78-1805

An Experimental and Analytical Study of Impact Forces in Elastic Mechanical Systems with Clearances

S. Dubowsky and M.F. Moening
Univ. of California, Los Angeles, CA 90024, Mech. Mach. Theory, 13 (4), pp 451-465 (1978) 14 figs, 1 table, 25 refs

Key Words: Joints (junctions), Impact response

Important performance limitations in mechanical systems result from correction clearances which cause rapid wear, and increased noise and vibration. Relatively little experimental investigation has been performed in this area, although a number of analytical studies have been carried out. Recent studies of the latter kind show the effect of clearances is to amplify, greatly, connection forces, and that the introduction of link flexibility tends to reduce these impact forces significantly. This study shows experimentally the validity of the analytical studies and the mitigating effects of link flexibility on impact forces.

78-1806

Dynamics of High-Speed Linkages with Elastic Members

A. Midha
Ph.D. Thesis, Univ. of Minnesota, 167 pp (1977) UM 7809704

Key Words: Linkages, Periodic response, Transient response

A great deal of attention has been given to the areas of analysis and synthesis of linkages with elastic members within the past fifteen years. Recently, kinematicians have turned to the use of structural dynamics analysis techniques for ease in handling complex linkage systems on computers. With a very few exceptions, little attention has been given to the economy of the computational methods. In this dissertation, after developing the equations of motion for a representative four-bar crank-rocker linkage, two computationally efficient numerical methods are generated. One method computes directly the periodic response, while the other is adaptable to the transient response analysis of the high-speed linkage.

MECHANICAL

78-1807

Sensitivity Analysis and Optimal Design of a Mechanical System with Intermittent Motion

R.C. Huang, E.J. Haug, Jr., and J.G. Andrews
Div. of Materials Engrg., Univ. of Iowa, Iowa City, IA, J. Mech. Des., Trans. ASME, 100 (3), pp 492-499 (July 1978) 6 figs, 1 table, 11 refs

Key Words: Intermittent motion, Weapons systems, Optimization, Steepest descent method

In this paper, a specific weapon recoil mechanism is treated in order to illustrate the problem class, to allow for development of a method of solution, and to provide a practical test of the method. A steepest descent optimization method, developed for mechanical design applications is employed to solve illustrative optimal design problems. Generalizations of the method will be treated in a future paper.

78-1808

Evaluation of Mutual Radiation Impedances Between Circular Pistons by Impulse Response and Asymptotic Methods

P.R. Stepanishen
Dept. of Ocean Engrg., Univ. of Rhode Island, Kingston, RI 02881, J. Sound Vib., 59 (2), pp 221-235 (July 22, 1978) 7 figs, 1 table, 14 refs

Key Words: Pistons, Impact response (mechanical)

A general approach is presented to evaluate the mutual radiation impedance between circular pistons of arbitrary size and spacing in an infinite rigid planar baffle. The impedance is expressed as a Fourier transform of a generalized impulse response which is defined by an integral relationship. Although the integral must, in general, be numerically evaluated, several special cases of interest can readily be evaluated by using asymptotic techniques. Several asymptotic expressions for the mutual radiation impedance are developed and their limitations are noted. Numerical results are then presented for the generalized impulse response and mutual radiation impedance corresponding to pistons of equal size and arbitrary spacing.

PIPES AND TUBES

78-1809

Forced Vibration of Continuous System with Nonlinear Boundary Conditions

T. Watanabe
Faculty of Education, Yamanashi Univ., Kofu, Japan, J. Mech. Des., Trans. ASME, 100 (3), pp 487-491 (July 1978) 6 figs, 13 refs

Key Words: Piping, Nuclear reactor components, Forced vibration, Continuous beams

This paper deals with the nonlinear vibration problem concerning mechanical equipment-piping systems in nuclear power plants and others. An analytical method by approximate solutions is introduced for these systems as a continuous system with nonlinear boundary conditions, and some numerical examples are shown. Finally some numerical results obtained as a continuous system are compared with those of a single-degree-of-freedom system.

78-1810

Cross-Flow Induced Vibrations in a Tube Bank - Vortex Shedding

L.K. Grover and D.S. Weaver
Dept. of Mech. Engrg., Rochester Inst. of Tech., Rochester, NY, J. Sound Vib., 59 (2), pp 263-276 (July 22, 1978) 9 figs, 1 table, 16 refs

Key Words: Tubes, Heat exchangers, Fluid-induced excitation, Vortex shedding

An experimental wind-tunnel facility which was developed specifically to study cross-flow induced vibrations in heat exchanger tube banks is described. Nineteen tubes in the center of the closely packed array were flexibly mounted in order that their response and interaction with the flow could be studied. The surrounding 116 tubes were fixed and could be easily removed to study the effect of tube bundle size on flow phenomena and tube response. Results are presented in this paper for vortex shedding.

78-1811

Cross-Flow Induced Vibrations in a Tube Bank -- Turbulent Buffeting and Fluid Elastic Instability

D.S. Weaver and L.K. Grover
Dept. of Mech. Engrg., McMaster Univ., Hamilton, Ontario, Canada, J. Sound Vib., 59 (2), pp 277-294 (July 22, 1978) 14 figs, 21 refs

Key Words: Tubes, Heat exchangers, Fluid-induced excitation, Turbulence

Experimental results are reported for a wind tunnel study of cross-flow induced vibrations in a tube bank. The rotated triangular array had a pitch ratio of 1.375 and consisted of 19 flexibly mounted tubes surrounded by 116 rigid, removable tubes. The natural frequency and damping of the flexibly mounted tubes could be carefully controlled. Details of the experimental facility and the vortex shedding behavior of the tube bank were reported in the first of these two companion papers. The turbulent buffeting and fluid elastic response are treated in this second paper. The effects on the fluid elastic threshold of the motion of surrounding tubes, damping and number of upstream rows of tubes are discussed.

78-1812

Dispersive Effects in Wave Propagation in Thin-Walled Elastic Tubes

T.B. Moodie and J.B. Haddow
Dept. of Mathematics, Univ. of Alberta, Edmonton, Alberta, Canada T6G 2E1, J. Acoust. Soc. Amer., 64 (2), pp 522-528 (Aug 1978) 12 figs, 5 refs

Key Words: Elastic waves, Wave propagation, Tubes, Elastomers, Fluid-induced excitation

A simple procedure, based on Love's approximate theory [The Mathematical Theory of Elasticity (Cambridge U.P., Cambridge, England, 1927), 4th ed.] for wave propagation in a bar, is proposed in order to consider dispersive effects in wave propagation in a thin-walled, fluid-filled, elastomer tube. It is assumed that the perturbation from steady flow in the tube is small enough that a linearized theory is valid, and that the elastic modulus of the tube is small compared with the bulk modulus of the fluid so that compressibility of the fluid can be neglected. The flexural rigidity of the tube wall, the inertia of the tube wall, and the radial inertia of the fluid are taken into account, and an approximate expression for the dispersion relation for the fundamental mode is obtained.

78-1813

Experiments on Fluidelastic Vibration of Cantilevered Tube Bundles

S.S. Chen and J.A. Jendrzejczyk
Components Tech. Div., Argonne National Lab., Argonne, IL, J. Mech. Des., Trans. ASME, 100 (3), pp 540-548 (July 1978) 9 figs, 6 tables, 3 refs

Key Words: Tubes, Fluid-induced excitation, Interaction: structure-fluid, Coupled response, Periodic response, Natural frequencies, Mode shapes

This paper presents the results of three series of experiments on coupled tube/fluid vibration. Natural frequencies and mode shapes of coupled modes as well as steady-state responses are measured for each tube bundle. An analysis is also made for each test. Experimental data and analytical predictions are found to be in good agreement.

78-1814

Torsional Oscillations of an Infinite Cylindrical Elastic Tube Under Large Internal and External Pressure

H. Engin and E.S. Suhubi
Tech. Univ. of Istanbul, Turkey, Intl. J. Engr. Sci., 16 (6), pp 387-396 (1978) 1 fig, 2 tables, 10 refs

Key Words: Tubes, Elastomers, Torsional vibration

This study is concerned with the small amplitude torsional oscillations of a hyperelastic infinite circular cylindrical thick tube made of a rubber-like material subjected to a large static internal and external pressure. The material is represented by a Mooney-type strain energy relation. The governing differential equation is first solved by the Frobenius method, then a variational approach, which is more suitable for numerical calculations, is developed. Several values for the natural frequencies are obtained.

78-1815

Cure Exchanger Acoustic Vibration

E.A. Barrington
Shell Oil Co., Houston, TX, Hydrocarbon Processing, 57 (7), pp 193-200 (July 1978) 10 figs, 2 tables, 9 refs

Key Words: Heat exchangers, Tubes, Acoustic resonance

Shell side acoustic vibrations can occur in tubular exchangers. Flow phenomena can generate unacceptably loud noise and potentially destructive pressure fluctuations due to the acoustic characteristics of the tubular heat exchanger. Such effects have been particularly noted in exchangers with natural gas, hydrogen-rich vapor, nitrogen gas or flue gas on the shell side. Trends in current design towards larger diameter tubulars and higher fluid velocities increase the likelihood of severe problems due to acoustic resonance. The occurrence of acoustic resonance is predicted and it is shown how to avoid the problem by proper design features.

PLATES AND SHELLS

(Also see Nos. 1707, 1731, 1788)

78-1816

Non-Linear Resonances in the Forced Responses of Plates. Part II: Asymmetric Responses of Circular Plates

S. Sridhar, D.T. Mook, and A.H. Nayfeh
Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Sound Vib., 59 (2), pp 159-170 (July 22, 1978) 9 refs

Key Words: Circular plates, Harmonic excitation, Nonlinear response, Perturbation theory

The dynamic analogue of the von Karman equations is used to study the forced response, including asymmetric vibrations and traveling waves, of a clamped circular plate subjected to harmonic excitations when the frequency of excitation is near one of the natural frequencies. The method of multiple scales, a perturbation technique, is used to solve the non-linear governing equations. The approach presented provides a great deal of insight into the nature of the nonlinear forced resonant response.

78-1817

Vibration of Circular Double-Plate Systems

A.S.J. Swamidas and V.X. Kunukkasseril
Dept. of Appl. Mechanics, Indian Inst. of Tech.,

Madras 600 036, India, J. Acoust. Soc. Amer., 63 (6), pp 1832-1840 (June 1978) 12 figs, 7 refs

Key Words: Circular plates, Composite structures, Vibration response

Vibrational characteristics of circular double-plate systems connected together by concentric, intermediate, elastic ring supports have been considered in this work. The analysis is based on the assumption that both of the plates are thin, elastic, and isotropic. Also, the plates are subjected to initial in-plane loads. The solutions are shown to be in terms of Bessel functions for the case of complete and annular (with equal in-plane loads) circular isotropic plate systems. The vibrational characteristics of the systems are illustrated by presenting numerical results for isotropic plate systems with one intermediate connection. When both the plates are identical with identical edge forces and boundary conditions, in-phase and out-of-phase vibration modes are observed.

78-1818

Acoustic Reflection from a Thick Plate with One Reinforcing Rib. Exact Integral Evaluation is Proved Superior to Integral Approximation in Analysis of Acoustic Reflections from a Timoshenko-Mindlin Plate Reinforced with One Rib

B.L. Woolley

Naval Ocean Systems Center, San Diego, CA, Rept. No. NOSC/TR-176, 198 pp (Dec 1977)
AD-A054 610/1GA

Key Words: Plates, Acoustic reflection, Timoshenko theory, Mindlin theory, Computer programs

The reflection of a plane sound wave from a thick, i.e., Timoshenko-Mindlin, fluid-loaded elastic plate reinforced with a stiffness member is investigated. The case is first solved without using integral approximation techniques. This solution gives relatively lower returns than those given by integral approximation techniques. The solution is also found by an integral approximation technique and then by an integral approximation technique taking into account leaky wave poles. The results of numerical calculations are presented and reviewed. Computer programs are given to carry out the calculations.

78-1819

Vibration Statistics of Thin Plates with Complex Form

A. Waberski

Silesian Technical Univ., Gliwice, Poland, AIAA J., 16 (8), pp 788-794 (Aug 1978) 10 figs, 20 refs

Key Words: Probability theory, Plates

A new mathematical method of calculation of the probabilistic characteristics of mechanical systems with complex geometry is presented. This method has been demonstrated on the example of random vibrating plates. This method is based on the application of certain special functions called R functions. In order to demonstrate this method, numerical calculations are presented of probabilistic characteristics for plates with complex geometry which have been clamped on the edge.

78-1820

A General Model for the Calculation of Thick Plates (And Rods)

G. Kumbetlian

Marine Institute, Constanta, Rumania, Rev. Roumaine Sci. Tech. - Mec. Appl., 23 (2), pp 249-262 (Mar/Apr 1978) 4 refs

Key Words: Plates, Rods, Harmonic excitation

This paper presents a general theoretical model for the calculation of thick plates (and rods) under biharmonic loads, which satisfies the large majority of loads occurring in practice.

78-1821

Design of Clamped Composite-Material Plates to Maximize Fundamental Frequency

C.W. Bert

School of Aerospace, Mech. and Nuclear Engrg., Univ. of Oklahoma, Norman, OK, J. Mech. Des., Trans. ASME, 100 (2), pp 274-278 (Apr 1978) 1 fig, 6 tables, 23 refs

Key Words: Rectangular plates, Composite materials, Fundamental frequency, Optimum design, Optimization

Methodology and equations are developed for maximizing the fundamental frequency (ω_f) of small-amplitude, free flexural vibration of a clamped, rectangular plate consisting of multiple, equal-thickness layers of the same unidirectional filamentary composite material. The synthesis is based on a concise, explicit equation for ω_f in terms of plate dimensions, density, and the anisotropic flexural and torsional rigidities. The equation is developed in the paper and shown to be quite accurate.

78-1822

Buckling and Vibration of In-Plane Loaded Plates

Treated by a Unified Ritz Approach
S.F. Bassily
Teledyne Systems Co., Northridge, CA., J. Sound Vib., 59 (1), pp 1-14 (July 8, 1978) 7 figs, 2 tables, 6 refs

Key Words: Rectangular plates, Flexural vibration, Buckling, Ritz method

The problem of the buckling and lateral vibration of rectangular plates subject to in-plane loads is treated by using a Ritz approach for both the determination of the middle surface stresses caused by the in-plane loading and the analysis of the consequent out-of-plane buckling and vibrational characteristics of the plates. Since the stress function formulation of the middle surface stress problem is formally analogous to the plate bending problem, the same type of admissible functions -- ordinary and degenerated beam vibration mode shapes -- are employed in the Ritz series for both parts of the problem. The approach permits the accurate treatment of plates subject to real in-plane loads, where the middle surface stresses may not be realistically representable by simple polynomials as has been assumed in earlier studies. Several numerical examples are presented, illustrating the applicability of the approach and giving an indication of the order of errors that may result in the determination of the out-of-plane characteristics of plates when using simplifying assumptions for the in-plane stress field.

78-1823

Vibration of the Elastic Cylindrical Shells (Zur Schwingung des elastischen Hohlzylinders)
U. Gamer
I. Institut f. Mechanik der Technischen Universität Wien, Vienna, Austria, Rev. Roumaine Sci. Tech. - Mec. Appl., 23 (1), pp 53-60 (Jan/Feb 1978) 2 tables, 15 refs
(In German)

Key Words: Tubes, Cylindrical shells, Vibration response, Amplitude

The cylindrically symmetric vibration of an incompressible elastic tube is investigated. A phase curve is derived by means of the law of conservation of energy. Potential energy is calculated for two types of materials: the Mooney material and the modified Mooney material. A phase diagram is presented for a vibration of Mooney material. Then the dependence of vibration duration on the amplitude is investigated.

78-1824

Torsional Vibrations of Pretwisted Cantilever Plates
K. Gupta and J.S. Rao
Indian Inst. of Tech., New Delhi, India, J. Mech. Des., Trans. ASME, 100 (3), pp 528-534 (July 1978) 7 figs, 6 tables, 12 refs

Key Words: Shells, Plates, Cantilever plates, Torsional vibration

A pretwisted cantilever plate is treated as a thin shallow shell. Its potential and kinetic energies in torsional vibration are determined by assuming an appropriate displacement field. Applying Hamilton's principle, the problem is reduced to a fourth-order ordinary differential equation with constant coefficients, which is solved to obtain the first four torsional frequencies of vibration. Plates of aspect ratios varying from 1.0 to 8.0 are analyzed with pretwist angles varying from 0 to 90 deg. Results of the present analysis are compared with existing theoretical and experimental results.

78-1825

Dynamics of Shells of Revolution Under Axisymmetric Load Involving Shear Deformation
Y. Tene and I. Sheinman
Faculty of Civil Engrg., Technion-Israel Inst. of Tech., Haifa, Israel, Computers Struc., 8 (5), pp 563-568 (May 1978) 11 figs, 7 refs

Key Words: Shells of revolution, Transverse shear deformation effects, Rotatory inertia effects, Finite difference theory

A general solution procedure, based on the linear theory, is presented for arbitrary shells of revolution subjected to arbitrary axisymmetric dynamic loads. The equations of motion admit shear deformation and rotational inertia. The numerical solution is obtained by Houbolt's method and by finite differences.

78-1826

Vibration and Buckling of Fluid-Filled Cylindrical Shells Under Torsion
J. Tani and H. Doki
Inst. of High Speed Mechanics, Tohoku Univ., Sendai, Japan, Nucl. Engr. Des., 48 (2/3), pp 359-365 (Aug 1978) 5 figs, 12 refs

Key Words: Cylindrical shells, Fluid-filled containers, Torsional excitation, Free vibration

On the basis of the Donnell-type equations modified with the transverse inertia force, the free vibration and the buckling of fluid-filled circular cylindrical shells under torsion are theoretically analyzed by using Galerkin's method. The fluid is assumed to be incompressible, irrotational and inviscid. Calculations are carried out for a simply-supported typical shell. It is found that the natural frequency of the shell under torsion decreases rapidly with the internal fluid, but the buckling load of the fluid-filled shell agrees precisely with that of the empty one.

78-1827

Studies on the Failure of Stiffened Cylindrical Shells Subjected to Dynamic Loads

C.A. Ross, R.L. Sierakowski, I.K. Ebcioglu, C.C. Schauble, and C.F. Yen

Graduate Engrg. Center., Florida Univ., Eglin AFB, FL, Rept. No. AFOSR-TR-78-0697, 249 pp (Dec 31, 1977)

AD-A053 954/4GA

Key Words: Cylindrical shells, Stiffened shells, Blast effects, Energy methods

The major objective of this study was to investigate the effects of axial stiffening of cylindrical shells subject to transverse blast loadings. Two existing methods for predicting dynamic response of cylindrical shells were modified to include axial stiffening. A semi-analytical energy method was chosen as a first cut design predictor and tables of normalized deflection versus external energy imparted to the structure are presented. In addition a more detailed analytical energy method was modified to include axial stiffening. In both cases the stiffeners were introduced by simply adding terms to the kinetic and potential energy terms of the basic shell equations rather than introducing membrane-bending coupling by use of more complicated anisotropic constitutive relations.

STRUCTURAL

78-1828

Travelling-Wave-Induced Instability of Structures

M. Farshad and I. Tadjbakhsh

School of Engrg., Pahlavi Univ., Shiraz, Iran, J. Franklin Inst., 305 (6), pp 343-350 (1978) 2 figs, 11 refs

Key Words: Seismic excitation, Ground motion, Structural members, Dynamic stability

The effect of transmission time of propagating disturbances on the dynamic instability of structures is discussed in this paper. Through a parametric study it is shown that for certain values of transmission time and wave frequency parameters, the structure may become dynamically unstable. An example is worked out, and graphical results depicting the regions of instability are presented.

78-1829

Transient Response of Continuous Viscoelastic Structural Members

W.D. Pilkey and J.S. Strenkowski

Dept. of Mech. and Aerospace Engrg., Virginia Univ., Charlottesville, VA., Rept. No. UVA/525303/MAE-78/102, 33 pp (Mar 1978)

AD-A054 255/5GA

Key Words: Structural members, Viscoelastic media, Modal analysis, Beams, Plates

A comprehensive theory for the dynamic response of linear continuous viscoelastic structural members if formulated with a modal analysis. The constitutive relation is in the form of a hereditary integral. A general set of formulas is derived that may be used for both non-self-adjoint and self-adjoint systems of governing equations of motion. Applications include a Voigt-Kelvin beam and a viscoelastic circular plate.

78-1830

Transient Analysis of Structural Members by the CSDT Riccati Transfer Matrix Method

W.D. Pilkey and F.H. Chu

Dept. of Mech. and Aerospace Engrg., Virginia Univ., Charlottesville, VA., Rept. No. UVA/525-303/MAE78/103, 38 pp (Mar 1978)

AD-A054 256/3GA

Key Words: Structural members, Numerical analysis, Transient response, Transfer matrix method, Bars, Beams

A method for direct integration of the dynamic governing partial differential equations of motion for structural members is presented. This technique is called the continuous space discrete time (CSDT) Riccati transfer matrix method. Numerical results for bar and beam example problems indicate that the method is numerically stable and accurate for calculating the dynamic response of linear structural members.

78-1831

Optimum Design of Bridge Girders for Electric Overhead Traveling Cranes

S.S. Rao

Dept. of Mech. Engrg., Indian Inst. of Tech., Kanpur-16, India., J. Engr. Indus., Trans. ASME, 100 (3),

pp 375-382 (Aug 1978) 4 figs, 5 tables, 18 refs

Key Words: Girders, Overhead cranes, Shock absorption, Design techniques

The problem of the design of box-type bridge girders for electric overhead traveling cranes is formulated as a minimum weight design problem with inequality constraints. The restrictions placed on the design problem include limitations on the maximum allowable deflections and stresses as well as on the shock absorbing capacity during accidental collision. The overall stability and rigidity considerations are also taken into account. Several load conditons, as per the code specifications, are considered in the design problem. The resulting nonlinear programming problem is solved by using an interior penalty function method. Numerical examples are given to illustrate the effectiveness of the approach. The resulting computer program is used to make a sensitivity analysis of the problem.

78-1832

How to Design Walls for Desired STC Ratings

R.E. Jones

Forest Products Lab., Forest Service, U.S. Dept. of Agriculture, S/V, Sound Vib., 12 (8), pp 14-17 (Aug 1978) 4 figs, 1 table, 2 refs

Key Words: Walls, Noise barriers, Sound transmission loss

Sound Transmission Class STC values typical of several common wall systems are presented to illustrate a range of STC performance from about 35 to 65. The effectiveness of single-panel and double-panel designs is contrasted and a technique for calculating the transmission loss below the coincidence frequency is summarized.

78-1833

Effect of Sound-Absorptive Facings on Partition Airborne-Sound Transmission Loss

S.M. Brown, J. Niedzielski, and G.R. Spalding

Res. and Dev. Center, Armstrong Cork Co., Lancaster, PA 17604, J. Acoust. Soc. Amer., 63 (6), pp 1851-1856 (June 1978) 5 figs, 2 tables, 12 refs

Key Words: Sound transmission loss, Walls, Coatings

Laboratory measurements of the improvement of partition airborne-sound transmission loss in the presence of sound-absorptive partition facings are presented. For a double-leaf partition of 1/2-in.-thick gypsum board on 2 X 4-in. studs, the application of such facings has led to improvements in transmission loss in excess of 10 dB in the 1/3-octave bands above 1 kHz. Corresponding, but smaller, improvements have been measured at lower frequencies.

78-1834

The Riccati Transfer Matrix Method

G.C. Horner and W.D. Pilkey

Mechanical Technology Inc., Latham, NY, J. Mech. Des., Trans. ASME, 100 (2), pp 297-302 (Apr 1978) 1 fig, 4 tables, 18 refs

Key Words: Transfer matrix method, Structural members, Shafts, Rotors

The Riccati transfer matrix method is a new technique for analyzing structural members. This new technique makes use of an existing large catalog of transfer matrices for various structural members such as rotating shafts. The numerical instability encountered when calculating high resonant frequencies, static response of a flexible member on a stiff foundation, or the response of a long member by the transfer matrix method is eliminated by the Riccati transfer matrix method. The computational time and storage requirements of the Riccati transfer matrix method are about half the values for the transfer matrix method. A rotating shaft analysis demonstrates the numerical accuracy of the method.

TIRES

78-1835

Improved Tire/Wheel Concept

P.M. Harper, Sr.

Langley Res. Center, NASA, Langley Station, VA., Rept. No. N78-22374/0, NASA-CASE-LAR-11695-1, 12 pp (Apr 6, 1978)

Sponsored by NASA

PAT-APPL-SN-893 865/GA

Key Words: Aircraft tires, Vehicle wheels, Wheels

A tire and wheel assembly is described in which a low profile pneumatic tire has sidewalls which deflect inwardly under load and a wheel has a rim featuring a narrow central channel and extended rim flanges from the combination. The extended rim flanges support the tire sidewalls under static and dynamic loading conditions to produce a combination particularly suited to aircraft applications.

SYSTEMS

ABSORBER

78-1836

Alternative Tuned Absorbers for Steady State Vibration Control of Tall Structures

R.L. Jenniges and D.A. Frohrib
Dept. of Mech. Engrg., The Design Center, Univ. of Minnesota, Minneapolis, MN, J. Mech. Des., Trans. ASME, 100 (2), pp 279-285 (Apr 1978) 13 figs, 6 refs

Key Words: Tuned dampers, Vibration absorbers (equipment), Multistory buildings, Periodic response, Flexural vibration, Torsional vibration

Two forms of damped vibration absorbers are evaluated to describe their value in reducing steady state vibration of tall buildings. The first model contains a set of two identical one-degree-of-freedom elements symmetrically mounted in a horizontal plane on either side of the building's long axis. An alternate model has independent translational and torsional elements mounted at the building's center. Damping parameters are included for building funamental bending and torsion modes to evaluate those effects on response. The sensitivity of absorber performance to absorber-building mass ratio μ is of interest to minimize the size of the absorber. Performance of the absorber models was compared based on maximum transmissibility and a quality integral, which is an integrated transmissibility over a frequency spectrum based on amplification at a point on the building top.

78-1837

Response Spectra Design Methods for Tuned Equipment-Structure Systems

J.M. Kelly and J.L. Sackman
Dept. of Civil Engrg., Univ. of California, Berkeley, CA 94720, J. Sound Vib., 59 (2), pp 171-179 (July 22, 1978) 2 figs, 8 refs
Sponsored by the Defense Nuclear Agency

Key Words: Equipment response, Equipment mounts, Tuned damping, Response spectra, Design techniques

A description is given of a design method that allows response spectra to be used to estimate maximum displacements and accelerations in equipment-structure systems. The type of system considered involves light equipment tuned to a natural frequency of the structure. The solution is developed by using transform methods, residue theory and asymptotic analysis. A very simple result is obtained which should be of value to designers of equipment, equipment mountings and non-structural components in structures subject to dynamic loading. The simple nature of the result is explained by a direct physical interpretation of the response.

78-1838

The Steady State Response of Systems with Hardening Hysteresis

R.K. Miller
Dept. of Mech. and Environmental Engrg., Univ. of California, Santa Barbara, CA., J. Mech. Des., Trans. ASME, 100 (1), pp 193-198 (Jan 1978) 6 figs, 9 refs

Key Words: Periodic response, Hysteretic damping, Viscous damping, Single degree of freedom systems, Multi degree of freedom systems

A physical model for hardening hysteresis is presented. An approximate analytical technique is used to determine the steady-state response of a single-degree-of-freedom system and a multi-degree-of-freedom system incorporating this model. Certain critical model parameters which determine the general nature of the responses are identified.

78-1839

Analysis of Performance of Pneumatic Impact Absorbers

M.S. Hundal
Dept. of Mech. Engrg., Univ. of Vermont, Burlington, VT, J. Mech. Des., Trans. ASME, 100 (2), pp 236-241 (Apr 1978) 4 figs, 7 tables, 5 refs

Key Words: Absorbers, Pneumatic dampers

Performance of impact absorbers employing a pneumatic damper and a linear spring in parallel is analyzed. The governing nonlinear differential equations are derived and converted to nondimensional form. For the case of a damper with fixed area orifice the equations are numerically integrated. Performance charts are presented in terms of three dimensionless parameters: mass, spring stiffness and orifice area ratio. Then, a second case is considered in which the damper orifice area is made to vary in two stages.

NOISE REDUCTION

(Also see Nos. 1862, 1869, 1872)

78-1840

Noise Control for Fan and Vent Shafts in Subways

P.Y.N. Lee
Wilson, Ihrig & Associates, Inc., 5605 Ocean View Dr., Oakland, CA 94618, Noise Control Engr., 10 (3), pp 102-107 (May/June 1978) 8 figs, 3 tables, 4 refs

Key Words: Fans, Subway cars, Noise control

Subway fan and vent shafts can be prominent sources of noise impact to both the adjacent community and to patrons in the subway stations. The author discusses the available methods for reduction of fan and train noise propagated out of vent shafts and fan noise propagated into stations. In addition, the results of fan noise measurements in station platforms and outside the fan shafts at existing rapid transit facilities are presented.

78-1841

Low Noise Propulsion System for General Aviation

B. Berdrow
Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen, West Germany, Rept. No. BMFT-FB-W-77-23, 384 pp (Dec 1977)
(In German)
N78-22108

Key Words: Propulsion systems, Noise reduction, Aircraft noise

The program described is aimed at the development of low noise propulsion systems of up to 200 HP for general aviation. The study is broken down into three stages (definition, production and testing). The objective of the program is a noise reduction of 10 dB(A) in comparison to the 1975 LBA noise economy, derived from standard passenger car engines. A comprehensive noise study on possible propellers (including shrouded propellers) forms the basis for the propeller rpm's required for low noise propulsion systems. The conversion of the high rpm's normal for passenger car engines to the low propeller rpm's required is via gearboxes, which are a fundamental problem dealt with. The solution to the problem is given in the definition stage. Studies on the installation of propulsion systems in existing airframes does not show particular problems.

78-1842

The Nine Tools of Noise Control

W. Fearon
Peabody Noise Control Inc., Dublin, OH, Des. News, 34 (2), pp 26-35 (June 19, 1978) 9 figs

Key Words: Noise reduction, Design techniques, Materials

The nine avenues open to the designer to make a product quiet, grouped into two major categories – designed-in solutions and added-on solutions, are discussed. Selection of materials for barriers, absorbers, dampers and vibration isolators is discussed.

78-1843

Diffraction of Arbitrarily Oriented Directional Sources by Rigid Planar Screens

G.W. Johnston
Inst. of Aerospace Studies, Univ. of Toronto, Downsview, Ontario, Canada M3H 5T6, J. Acoust. Soc. Amer., 64 (2), pp 665-676 (Aug 1978) 11 figs, 7 refs

Key Words: Noise barriers, Guardrails

An analysis has been carried out to determine the diffracted fields due to directional sources located near rigid planar screens with application to the suppression of noise by acoustic barriers, especially highway barriers. Firstly, the diffracted field due to an arbitrarily oriented point dipole source is obtained by source position differentiation using the classical exact results due to McDonald. The dipole results are then combined with the monopole results to obtain the diffracted fields due to a series of combined sources having arbitrary directivity and orientation with respect to the plane of the screen. It is noted that while the diffraction problem with simple sources and planar screens exhibits reciprocity, diffraction results obtained in the present problem do not exhibit reciprocity with respect to source and observer locations. Typical computed insertion loss results are shown indicating the trends associated with source directionality, source orientation, and source location.

AIRCRAFT

(Also see Nos. 1725, 1726)

78-1844

Modal Investigation of Lightweight Aircraft Structures Using Digital Techniques

R.W. Gordon, H.F. Wolfe, and R.D. Talmadge
Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH, Rept. No. AFFDL-TR-77-124, 66 pp (Dec 1977)
AD-A053 782/9GA

Key Words: Aircraft, Testing techniques, Natural frequencies, Mode shapes, Modal damping, Honeycomb structures

Digital impact response test techniques were used to measure the dynamic properties of lightweight aircraft structures to include natural frequencies, mode shapes and modal damping. Two different types of structures were tested, honeycomb and skin-stiffened panels. The digital impact response method used consisted of applying a transient force pulse to the structure, measuring the structure's response at various points, digitizing, calculating the transfer functions using fast Fourier transforms, and determining the dynamic properties from these data. A second method was used on these same structures for direct comparison purposes. This method was an analog technique using sine sweep tests and accelerometer mapping.

78-1845

Effects of Cavity Resonances on Sound Transmission into a Thin Cylindrical Shell

L.R. Koval
Dept. of Mech. and Aerospace Engrg., Univ. of Missouri-Rolla, Rolla, MO 65401, J. Sound Vib., 59 (1), pp 23-33 (July 8, 1978) 4 figs, 7 refs
Sponsored by NASA

Key Words: Aircraft noise, Internal noise, Noise reduction, Cylindrical shells, Cavity resonance, Mathematical models

In the context of the transmission of airborne noise into an aircraft fuselage, a mathematical model is presented for the effects of internal cavity resonances on sound transmission into a thin cylindrical shell. The "noise reduction" of the cylinder is defined and computed, with and without including the effects of internal cavity resonances. As would be expected, the noise reduction in the absence of cavity resonances follows the same qualitative pattern as does transmission loss.

78-1846

An Acoustic Range for the Measurement of the Noise Signature of Aircraft During Flyby Operations

D.A. Hilton and H.R. Henderson
Langley Res. Center, NASA, Hampton, VA 23665, Noise Control Engr., 10 (3), pp 120-126 (May/June 1978) 15 figs, 6 refs

Key Words: Aircraft noise, Acoustic signatures, Measurement techniques

The authors present a detailed description of the Remotely Operated Multiple Array Acoustic Range currently operated by NASA. Also given are examples of actual measurements that demonstrate ROMAAR's application to ground noise footprint measurement for different types of aircraft.

78-1847

Noise Prediction Technology for CTOL Aircraft

J.P. Raney
Langley Res. Center, NASA, Langley Station, VA., Rept. No. NASA-TM-78700, L-12234, 16 pp (May 1978)
N78-23875

Key Words: Aircraft noise, Noise prediction, Propulsion systems

The application of a new aircraft noise prediction program to CTOL noise prediction is outlined. Noise prediction is based on semiempirical methods for each of the propulsive system noise sources, such as the fan, the combustor, the turbine, and jet mixing, with noise-critical parameter values derived from the thermodynamic cycle of the engine. Comparisons of measured and predicted noise levels for existing CTOL aircraft indicate an acceptable level of accuracy.

78-1848

Noise From Engine Thrust Reversal of Landing Aircraft

R.F. Higginson and A.J. Rennie
National Physical Lab., Teddington, UK, Rept. No. NPL-Ac-83, 63 pp (Aug 1977)
N78-23098

Key Words: Aircraft noise, Engine noise, Noise measurement

Measurements were made of aircraft noise, with particular reference to the levels of engine thrust reversal noise of different aircraft types at and near to London Airport - Gatwick. The object was to determine the contribution of reverse thrust noise to the total noise exposure at points on the ground. The results show that generally this contribution is small in relation to that of the principal sources of noise, aircraft taking off and climbing out.

78-1849

Community Noise Exposure Resulting from Aircraft Operations. Volume 1. Acoustic Data on Military Aircraft

J.D. Speakman, R.G. Powell, and J.N. Cole
Aerospace Medical Res. Lab., Wright-Patterson AFB, OH, Rept. No. AMRL-TR-73-110-VOL-1, 51 pp (Nov 1977)
AD-A053 699/5GA

Key Words: Aircraft noise, Noise measurement

This report is one of a series describing the research program undertaken by the Aerospace Medical Research Laboratory to develop the procedures (NOISEMAP) and data base (NOISEFILE) for predicting community noise exposure resulting from military aircraft operations. It presents the results of field test measurements to define the single event noise produced on the ground by military fixed wing aircraft during controlled level flyovers and ground runups.

78-1850

Community Noise Exposure Resulting from Aircraft Operations. Volume 2. Acoustic Data on Military Aircraft: Air Force Bomber/Cargo Aircraft

J.D. Speakman, R.G. Powell, and R.A. Lee

Aerospace Medical Res. Lab., Wright-Patterson AFB, OH., Rept. No. AMRL-TR-73-110-VOL-2, 768 pp (Nov 1977)

AD-A053 700/1GA

Key Words: Aircraft noise, Noise measurement

This report presents the results of field test measurements to define the single event noise produced on the ground by military, fixed wing aircraft during controlled level flyovers and ground runups. For flight conditions, data are presented in terms of various acoustic measures over the range 200-25,000 feet minimum slant distance to the aircraft. For ground runups, data are presented as a function of angle and distance to the aircraft. All of the data are normalized to standard acoustic reference conditions of 59 F temperature and 70% relative humidity. Noise data are presented in this Volume 2 for many military aircraft.

78-1851

Community Noise Exposure Resulting from Aircraft Operations. Volume 3. Acoustic Data on Military Aircraft: Air Force Attack/Fighter Aircraft

J.D. Speakman, R.G. Powell, and R.A. Lee

Aerospace Medical Res. Lab., Wright-Patterson AFB, OH, Rept. No. AMRL-TR-73-110-VOL-3, 763 pp (Feb 1978)

AD-A053 701/9GA

Key Words: Aircraft noise, Noise measurement

This report presents the results of field test measurements to define the noise produced on the ground by military, fixed wing aircraft during controlled level flyovers and ground runups. For flight conditions, data are presented in terms of various acoustic measures over the range 200-25,000 feet minimum slant distance to the aircraft. For ground runups, data are presented as a function of angle and distance to the aircraft. All of the data are normalized to standard acoustic reference conditons of 59 deg. F temperature and 70% relative humidity. Noise data are presented in this Volume 3 for many military aircraft.

78-1852

Community Noise Exposure Resulting from Aircraft Operations. Volume 4. Acoustic Data on Air Force Trainer/Fighter Aircraft

J.D. Speakman, R.G. Powell, and R.A. Lee

Aerospace Medical Res. Lab., Wright-Patterson AFB, OH, Rept. No. AMRL-TR-73-110-VOL-4, 644 pp (Feb 1978)

AD-A053 702/7GA

Key Words: Aircraft noise, Noise measurement

This report presents the results of field test measurements to define the noise produced on the ground by military, fixed wing aircraft during controlled level flyovers and ground runups. For flight conditions, data are presented in terms of various acoustic measures over the range 200-25,000 feet minimum slant distance to the aircraft. For ground runups, data are presented as a function of angle and distance to the aircraft. All of the data are normalized to standard acoustic reference conditions of 59 deg. F temperature and 70% relative humidity. Noise data are presented in this Volume 4 for many military aircraft.

78-1853

Long-Distance Focusing of Concorde Sonic Boom

L. Liszka

Kiruna Geophysical Inst., S-981 01 Kiruna 1, Sweden, J. Acoust. Soc. Amer., 64 (2), pp 631-635 (Aug 1978) 9 figs, 9 refs

Key Words: Aircraft noise, Sonic boom

Infra-acoustic signals from supersonic flights of Concorde are regularly recorded in northern Sweden at distances up to 5000 km from the aircraft. Relatively high signal amplitudes (up to 0.1 N/m^2) are explained by a kind of long-distance focusing effect. Principle and consequences of the focusing effect are discussed.

78-1854

Full Scale Crash Test Experimental Verification of a Method of Analysis for General Aviation Structural Crashworthiness

G. Wittlin, M.A. Gamon, and W.L. LaBarge

Lockheed-California Co., Burbank, CA., Rept. No.

LR-28306, FAA-RD-77-188, 424 pp (Feb 1978)
AD-A054 154/0GA

Key Words: Crash research (aircraft)

The results of the Task II effort to experimentally verify a method of analysis of the structural dynamics response of general aviation airplanes subjected to a crash environment are presented. Included in this report is a description of the preparation for the performance of four instrumented full-scale crash tests involving a single-engine, high wing type airplane. All crash testing was performed at the NASA Langley Impact Dynamics Research Facility (IDRF). The crash tests involved a wide range of impact attitudes and included one impact into a soil covered terrain.

78-1855

Tests of Crash-Resistant Fuel System for General Aviation Aircraft

W.M. Perrella, Jr.

Experimental Center, National Aviation Facilities, Atlantic City, NJ, Rept. No. FAA-NA-77-48, FAA/RD-78-28, 32 pp (Mar 1978)
AD-A054 141/7GA

Key Words: Crash research (aircraft), Fuel tanks

A significant percentage of general aviation aircraft accidents result in postcrash fires due to the ignition of fuel spillage, often contributing injury or death to the aircraft occupants. Testing was performed to demonstrate the performance of light-weight, flexible, crash-resistant fuel cells combined with the use of frangible fuel line couplings. Included in these tests were three full-scale crash tests of a typical light twin aircraft.

BUILDING

(Also see Nos. 1717, 1744, 1745, 1746, 1747)

78-1856

Development of an Empirical Relationship for the Prediction of Damping in Steel-Framed Buildings

T.J. Rusnak

Army Military Personnel Center, Alexandria, VA, 219 pp (May 3, 1978)
AD-A054 438/7GA

Key Words: Buildings, Damping, Prediction techniques

Test data from the forced vibration and ambient experiments on actual structures are used as input to a regression analysis routine to develop equations for the prediction of damping in steel-framed buildings. The data is categorized by building height and building width (the dimension in the direction parallel to the applied forces). The best resulting equation is used as the basis for a new design methodology to predict damping. This methodology consists of using the prediction equation in a situation where a set of conditions are satisfied. These conditions pertain to the particular characteristics of the structure and the approximate level of excitation which is expected. It is anticipated that this methodology will be especially useful in the early stages of design. Included also are two types of sensitivity analysis which indicate the amount of variation in displacement response that can be expected by using the developed prediction equation.

78-1857

Inelastic Response of Multistory Buildings to Tornadoes

M. Seniwongse

Ph.D. Thesis, Texas Tech Univ., 400 pp (1977)
UM 7810851

Key Words: Multistory buildings, Wind-induced excitation

The purpose of this research project is to perform a computer study of the response of multistory steel frame buildings to tornadic winds in order to determine if such structures can be economically designed to withstand tornadoes and, if so, what design provisions would be appropriate. A number of factors and their effects on the building response are investigated. These factors include various parameters describing the tornado windfield, the effects of dynamic as well as static response, and the influence of yielding, non-structural stiffness and strength, and $P - \Delta$ moments.

78-1858

Earthquake Simulation Tests of a Nine Story Steel Frame with Columns Allowed to Uplift

A.A. Huckelbridge

Ph.D. Thesis, Univ. of California, Berkeley, 177 pp (1977)
UM 7812455

Key Words: Buildings, Seismic response, Computerized simulation, Experimental data

This thesis presents experimental and analytical response data for a model nine-story building frame under seismic excitation, both with and without supplementary anchorage of the columns provided. The experimental work was carried out on the shaking table of the U.C. Berkeley Earthquake Simulator Laboratory.

CONSTRUCTION

78-1859

Road Construction Noise Prediction and Measurement – A Case Study

D.M. Martin and A.V. Solaini

Transport and Road Res. Lab., Crowthorne, UK, Rept. No. TRRL-LR-758, 28 pp (1977)

PB-280 508/3GA

Key Words: Noise prediction, Noise measurement, Construction equipment, Earth handling equipment

Noise predictions and measurements have been made during the earthworks phase of a road construction scheme in order to illustrate the roles that noise prediction and measurement can play is assessing noise control strategies in earthworks operations. Measurements were made over periods of six hours or more.

FOUNDATIONS AND EARTH

(See Nos. 1749, 1837)

HUMAN

78-1860

Measurement of the Energy Dissipated in the Hand and Arm Whilst Using Vibratory Tools

J.S. Anderson and R.A.C. Boughtflower

Dept. of Mech. Engrg., The City Univ., London EC1V4PB, UK, Appl. Acoust., 11 (3), pp 219-224 (July 1978) 3 figs, 6 refs

Key Words: Tools, Vibratory tools, Human response

Acceleration levels during hand-held grinding have been measured. By controlling the input to a vibration shaker the same acceleration levels were introduced into a specially designed handle gripped by a human hand. From measurements of force, acceleration and phase the power dissipated in the hand was calculated in third-octave bands. Approximate agreement was achieved with power dissipation estimates obtained form the acceleration alone by assuming the hand-arm system to be a linear, single degree of freedom system. The power dissipated is proposed as an important parameter affecting vibration-induced white finger.

78-1861

Vibration Aspects of Ride Quality Modeling for the DOT PTACV - Theory and Experiment

R. Katz

Metrex Div., MITRE Corp., McLean, VA., Rept. No. FRA/ORD-78/02, 59 pp (Dec 1977)

PB-279 846/0GA

Key Words: Ground effect machines, Ride dynamics, Human response

An important aspect of passenger ride comfort in a transportation vehicle is the acceleration level of the passenger cabin. In order to incorporate ride quality into the design process of such vehicles, it is necessary to have reasonably validated analytical models to predict the acceleration levels at frequencies which affect passenger ride comfort. The purpose of the report is to discuss the suitability of analytical models used to predict the heave acceleration in the passenger cabin of The Department of Transportation's Prototype Tracked Air Cushion Vehicle (PTACV). The basis of this evaluation is a comparison of theoretical predictions from an analytical model, typical of those in common usage today, with measured responses accumulated during testing of the PTACV on its test track.

ISOLATION

78-1862

One Stage and Two Stage Vibration Isolators as Applied to High Speed Textile Spindles to Achieve Noise Reduction

L.W. Foster

Lord Kinematics, Erie, PA, J. Mech. Des., Trans. ASME 100 (1), pp 33-40 (Jan 1978) 11 figs, 7 refs

Key Words: Textile spindles, Vibration isolators, Noise reduction

This paper describes the use of two types of elastomeric vibration isolators located between the spindle bolster and the rail to achieve reductions of vibration and noise levels associated with the spindle-bobbin-rail subsystem of spinning frames. The two types of elastomeric isolators employed are: a single-stage isolator where a bonded elastomeric mounting of annular design is placed between the bolster and the rail, and a two-stage isolator which incorporates an annular intermediate mass element between two annular elastomeric sections that provide the interfaces to the spindle and to the rail.

78-1863

Optimization of Pneumatic Vibration Isolation System for Vehicle Suspension

E. Esmailzadeh
Dept. of Mech. Engrg., Massachusetts Inst. of Tech., Cambridge, MA, J. Mech. Des., Trans. ASME, 100 (3), pp 500-506 (July 1978) 13 figs, 12 refs

Key Words: Suspension systems (vehicles), Vibration isolators, Pneumatic springs, Optimization

An optimization technique is applied to evaluate the optimum values of many parameters involved for which the maximum transmitted motion to the body would be minimum over the broad frequency range. Theoretical expressions for the transmissibility of the body and the wheel, optimum values of mass ratio, stiffness ratio and damping ratio are presented. Design data are presented nondimensionally for parameter variations which are sufficiently broad to encompass a wide range of practical engineering problems.

78-1864

Optimizing Railroad Freight Car Truck Suspension Systems Having Coulomb Damping

R.L. Bullock and D.B. Cooley
Standard Car Truck Co., Chicago, IL, J. Engr. Indus., Trans. ASME, 100 (3), pp 311-317 (Aug 1978) 4 figs, 4 tables

Key Words: Suspension systems (vehicles), Freight cars, Railroad cars, Coulomb friction

This paper describes the design process followed in developing a 100 ton freight car truck suspension system having coulomb damping. Classical linear vibration analysis was used for the conceptual design phase. Within the constraints placed upon truck suspension systems, a constant damping parameter, i.e., the ratio of friction force to static force imparted by the base, for all load conditions was established as a design goal. Optimization of the actual design parameters and comparison to existing truck suspensions was accomplished using the latest vehicle model developed by the AAR/TTD.

MECHANICAL

78-1865

Analytical and Experimental Studies of a Dynamic System with a Gap

S.F. Masri
Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, CA., J. Mech. Des., Trans. ASME, 100 (3), pp 480-486 (July 1978) 6 figs, 4 refs

Key Words: Forced vibration, Periodic response, Harmonic excitation, Mechanical systems, Motion-limiting stop

An analytical and experimental study is made of the forced vibration of a dynamic system with a motion-limiting stop, which is encountered in many practical cases involving mechanical equipment. An exact closed-form analytical solution is derived for the steady-state motion of the system when it is subjected to harmonic excitation. Experimental measurements with a mechanical model verify the analytical findings. The effects of various system parameters on the response are determined. Some interesting features of the motion are observed and compared to the jump resonance phenomenon exhibited by the solution of Duffing's equation.

METAL WORKING AND FORMING

78-1866

Experimental and Analytical Investigation of Self-Excited Chatter Vibrations in Metal Cutting

N. Saravanja-Fabris and A.F. D'Souza
Bell Telephone Labs., Naperville, IL, J. Mech. Des., Trans. ASME, 100 (1), pp 92-99 (Jan 1978) 12 figs, 22 refs

Key Words: Metal working, Chatter, Self-excited vibrations

Chatter in metal cutting is a nonlinear self-excited vibration of the limit cycle type. This investigation is concerned with the analysis of chatter from the viewpoint of the describing function. Vibrations with different frequencies and amplitudes were superimposed on the steady feed motion of the tool in orthogonal cutting in order to simulate chatter. The relationships between the oscillating cutting and thrust forces and tool vibrations are discussed from the point of view of energy transfer and describing functions. Experimentally obtained describing functions of the dynamically varying cutting process are given. The stability of a typical machine tool structure under primary chatter conditions with dynamical cutting process represented by its describing function is discussed.

78-1867

Investigation of the Cutting Process Dynamics in Turning Operations

K. Srinivasan and C.L. Nachtigal
Shell Development Co., Houston, TX, J. Engr. Indus., Trans. ASME, 100 (3), pp 323-331 (Aug 1978) 9 figs, 7 tables, 13 refs

Key Words: Cutting, Chatter, Machine tools, Parameter identification technique

This paper describes the application of a sequential equation error minimization technique to determine empirically the optimum parameter values in a predetermined set of force component models from dynamic cutting data. The identification technique was verified on an analog computer simulation of the dynamic behavior of a machine tool system. The identified parameter values were compared with the actual simulated values.

78-1868
Identification of Machining System Dynamics by Equation Error Minimization

K. Srinivasan and C.L. Nachtigal

Shell Development Co., Houston, TX, J. Engr. Indus., Trans. ASME, 100 (3), pp 332-339 (Aug 1978) 6 figs, 4 tables, 1 ref

Key Words: Parameter identification technique, Machine tools, Chatter, Self-excited vibration

The application of a sequential equation error minimization method to the identification of the dynamics of machining systems is described here. The development of the identification method was motivated by the need for models of machining system dynamics for the design of active chatter controllers. The dynamic cutting force parameters as well as the machine structure transfer function parameters are required for this task.

OFF-ROAD VEHICLES

78-1869
Off-Highway Hydraulic Noise

Auto. Engr., 86 (9), pp 34-40 (Sept 1978) 7 figs, 4 refs

Key Words: Off-highway vehicles, Agricultural machinery, Noise control

Sources of hydraulic noise and ways to minimize it are examined. Two specific examples of noise control are offered: one for a harvesting machine, the other for a rough-terrain forklift truck used by the military.

PUMPS, TURBINES, FANS, COMPRESSORS

(Also see Nos. 1766, 1794)

78-1870
Nonlinear Resonance as the Cause of Multiple Pure Tones

P.G. Vaidya and K.S. Wang

Boeing Commercial Airplane Co., Seattle, WA, J. Aircraft, 15 (8), pp 526-533 (1978) 4 figs, 14 refs

Key Words: Fans, Ducts, Noise generation, Resonant response, Noise reduction

When the fans of aeroengine ducts go supersonic, they often produce radiation at the subharmonics of blade-passage frequency, known as multiple pure tones (MPT). It has been shown that the conventional explanation, that these MPT's are created by the shock waves, is inadequate. An alternative mechanism based on the concept of a "strong interaction" between the harmonics is proposed. Expression for the governing equation for such an interaction is derived. The results show an improved agreement with observed data. The analysis has also led to several practical suggestions for a suppression of the noise.

78-1871
Controlling Fan Noise In and Around Power Plants

J.G. Funk

Environmental Elements Corp., Power, 122 (9), pp 114-117 (Sept 1978) 8 figs

Key Words: Fans, Noise reduction

A procedure for reducing the inlet, exhaust, and casing noise from forced- and induced-draft and primary-air fans is described.

78-1872
Generation and Suppression of Fan-Compressor Noise

S.L. Sarin

Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost, Rept. No. FOK-3-1823, 22 pp (1977) N78-22107

Key Words: Fans, Compressors, Aircraft noise, Noise reduction, Acoustic linings

The generation mechanism of fan-compressor noise during the landing phase of an aircraft is examined. Various techniques (reduction of interaction tones at the source, flow choking, use of acoustic liners) to suppress this component of total aircraft noise are described. It is concluded that the choice of an optimum liner for the maximum possible suppression demands a predictive capability with regard to liner optimum impedance, and its translation into a real hardware, and liner performance.

RAIL

(Also see No. 1729)

78-1873

An Investigation of Techniques for Validation of Railcar Dynamic Analyses

W.J. Fallon, N.K. Cooperrider, and E.H. Law
Dept. of Mech. Engrg., Airzona State Univ., Tempe, AZ, Rept. No. FRA/ORD-78/19, 123 pp (Mar 1978)
PB-279 996/3GA

Key Words: Railroad cars, Freight cars, Interaction: rail-wheel, Mathematical models, Spectral energy distribution techniques

A linear model of the vertical dynamics of a railcar was validated by the application of spectral techniques to experimental data. Track input spectra were computed from test track surface measurements gathered in the TDOP test program. Acceleration measurements of a freight car were used to compute vehicle acceleration spectra in response to the test track. The corresponding response of the linear model was computed from the analytical transfer functions and experimental track input spectra. Validation of the linear model was based upon a comparison of corresponding analytical and experimental vehicle acceleration spectra. The truck suspension was isolated and analyzed from experimental measurements of corresponding truck and car body accelerations. Spectral functions were employed to evaluate the assumptions of suspension linearity.

78-1874

Dynamics of a High-Speed Sliding Power Collector in Consideration of Sliding Friction

K. Yoshida and T. Shimogo
Faculty of Engrg., Keio Univ., Yokohama, Japan, J. Mech. Des., Trans. ASME, 100 (2), pp 242-250 (Apr 1978) 18 figs, 1 table, 6 refs

Key Words: High speed transportation systems, Sliding power collector, Interaction: rail-wheel, Sliding friction, Mathematical models

Considering the sliding friction force produced between a contactor and a rigid collecting rail with a randomly wavy surface, the paper deals with the dynamics of a sliding power collector for a very-high-speed railway. An analytical model is formulated, which has two contact points and takes into account the pitching of a contactor, the stiffness of the sliding direction in a contactor support system, and the nonlinearity of the contact stiffness between a contactor and a rail. Mainly, the influences of the sliding friction and the contact stiffness on the dynamic characteristics, i.e., the contact force variation, the probability of contact break, etc., are investigated.

REACTORS

78-1875

Vibration Analysis of Heat Exchanger and Steam Generator Designs

M.J. Pettigrew, Y. Sylvestre, and A.O. Campagna
Chalk River Nuclear Labs., Atomic Energy of Canada, Ltd., Chalk River, Ontario K0J IJ0, Canada, Nucl. Engr. Des., 48 (1), pp 97-115 (June 1978) 20 figs, 2 tables, 25 refs

Key Words: Nuclear reactor components, Heat exchangers, Boilers, Fluid-induced excitation, Design techniques

A thorough flow-induced vibration analysis of nuclear components such as heat exchangers and steam generators is essential at the design stage to ensure good performance and reliability. This paper presents our approach and techniques in this respect.

78-1876

Engineering of Nuclear Power Facilities for Earthquake Loads

A.H. Hadjian
Los Angeles Power Div., Norwalk, Bechtel Power Corp., P.O. Box 60860 - Terminal Annex, Los Angeles, CA 90060, Nucl. Engr. Des., 48 (1), pp 21-47 (June 1978) 15 figs, 6 tables, 32 refs

Key Words: Nuclear power plants, Seismic design

The state-of-knowledge to engineer nuclear power facilities for earthquake loads is reviewed as it was collectively presented at the fourth SMiRT Conference. All aspects of the design process are critically examined starting with the definition of ground motion. Both past achievements in each of the several areas of endeavor, and the gaps in our knowledge that need further research and study are emphasized. Several alternatives to above ground facilities are reviewed, and issues are raised regarding easy solutions to very complex problems associated with these alternatives.

78-1877

Seismic Response of Gas-Cooled Fast Breeder Reactor Core Structural Assembly Via Modal Synthesis

T.H. Lee and A.S. Chuang

General Atomic Co., San Diego, CA 92138, Nucl. Engr. Des., 49 (3), pp 269-277 (Sept 1978) 8 figs, 17 refs

Key Words: Seismic response, Nuclear reactors, Modal synthesis

An investigation has been conducted to determine theoretically the dynamic response of the GCFR core support structural assembly when subjected to boundary excitation from seismic disturbances. The system analyzed consists of a thick grid plate to which many core elements are vertically attached. The dynamic problem was solved by synthesizing component modes of two substructures and treating them as continuous subsystems. Numerical system modal data and time-history response results are presented.

RECIPROCATING MACHINE

(Also see No. 1769)

78-1878

Influence of the Periodic Variations of the Mass Inertia on the Torsional Vibrations of a Four-Cylinder Engine (Einfluss der periodischen Schwankung des Massentragheitsmomentes auf die Torsionsschwingungen des Vierzylinder-Motors)

H. Klier

Lustheide 95, D-5060 Bergisch Gladbach 3, Germany, MTZ Motortech. Z., 39 (7/8), pp 341-345 (July/Aug 1978) 3 figs, 3 tables, 4 refs

(In German)

Key Words: Engine vibration, Diesel engines, Torsional vibration, Damping

This paper describes the effect of periodic mass inertia variation of crank assembly. For this purpose, series of torsional vibration measurements were made by systematically changing the sizes of mass inertia moment at the flywheel- and front end side of the crankshaft. The engine used is a small fast running four-cylinder diesel, designed for passenger cars.

78-1879

Current Alternatives in Exhaust System Acoustical Evaluation

L.J. Eriksson

Nelson Industries, Inc., Stoughton, WI, S/V, Sound Vib., 12 (8), pp 18-25 (Aug 1978) 17 figs, 1 table, 21 refs

Key Words: Engines, Exhaust noise

Various procedures for the evaluation of exhaust system performance are presented and discussed. Analytical as well as experimental techniques are considered. Comparisons are made with measurements on actual engine exhaust noise. The major approaches are ranked with respect to accuracy and cost.

ROAD

(Also see No. 1728)

78-1880

Important Data for Lateral Vehicle Dynamics (Wichtige Daten f. die Kurshaltung von Kraftfahrzeugen)

M. Mitschke

Institut f. Fahrzeugtechnik, Hans-Sommer-Strasse 4, 3300 Braunschweig, Automobiltech. Z., 80 (6), pp 263-270 (June 1978) 5 figs, 4 tables, 7 refs

Key Words: Automobiles, Steering effects, Lateral response

Four frequency responses concerning the driver-vehicle-system are examined herein. Input is the steering wheel angle, outputs are yaw velocity, sideslip angle, lateral acceleration and steering wheel torque. The velocity is kept constant.

78-1881

Research Safety Vehicle - Phase II. Volume II. Comprehensive Technical Results

N. DiNapoli, M. Fitzpatrick, C. Strother, D. Struble, and R. Tanner

Minicars, Inc., Goleta, CA., Rept. No. DOT-HS-803 250, 609 pp (Nov 1977)

PB-280 153/8GA

Key Words: Collision research (automotive)

Phase I identified trends leading to the desired national social goals of the mid-1980's in vehicle crashworthiness, crash avoidance, damageability, pedestrian safety, fuel economy, emissions and cost, and characterized an RSV to satisfy them. In Phase II an RSV prototype was designed, developed and tested to demonstrate the feasibility of meeting these goals simultaneously.

ROTORS

(Also see Nos. 1752, 1834)

78-1882

A Simple Stability Analysis for Flexible Rotors in Tilting Pad Bearings

E.A. Bulanowski
Solid Mechanics Res. and Advanced Product Dev., Delaval Turbine, Inc., Trenton, NJ., J. Mech. Des., Trans. ASME, 100 (1), pp 165-172 (Jan 1978) 10 figs, 1 table, 5 refs

Key Words: Rotor-bearing systems, Tilting pad bearings, Stability analysis

A simplified stability analysis for flexible rotors in tilting pad bearings is developed which provides a convenient and practical approach for the consideration of nonsynchronous vibrations during the design phase of rotor bearing systems. This paper demonstrates that the free vibrations, and hence the system damping factor, of a distributed mass flexible rotor in tilting pad bearings may be analyzed using a single mass, two tier spring-damper model. The relationship between the system damping factor and rotor stability is discussed. Nonsynchronous tilting pad bearing characteristics are incorporated into the expression for the damping factor, and nondimensional curves are presented which establish values of the damping factor as a function of operating speed, critical speed, bearing clearance and Sommerfeld number. The subject curves provide a quick method for establishing stability guidelines during rotor design and for comparing existing rotor bearing systems.

78-1883

The Stability of an Asymmetric Rotor in Damped Supports

A.J. Smalley, J.M. Tessarzik, and R.H. Badgley
Mechanical Technology, Inc., Latham, NY, ASME Paper No. 78-GT-172

Key Words: Rotor-bearing systems, Tilting-pad bearing

A general-purpose method of evaluating the stability of an asymmetric flexible rotor, mounted in symmetric damped bearings, is defined. This method evaluates the complex eigenvalues of the rotor system by solving the equations of motion in a rotating coordinate frame. The application of this method to a rotor mounted in tilting-pad bearings is demonstrated. The observed behavior of a number of different rotor configurations is compared with corresponding predictions of stability.

78-1884

The Dynamics of Multi-Rotor Systems Supported on Oil Film Bearings

A.G. Holmes, C.M.M. Ettles, and I.W. Mayes
Dept. of Mech. Engrg., Imperial College, London, UK, J. Mech. Des., Trans. ASME 100 (1), pp 156-164 (Jan 1978) 12 figs, 9 refs

Key Words: Rotor-bearing systems, Fluid-film bearings, Oil film bearings, Alignment, Self-excited vibrations

The self-excited transverse vibration of an elastic multirotor system due to vertical misalignment of the support bearings is investigated using initial value problem techniques. The equations of motion are expressed in terms of the free-free modes of the shaft and the modal coefficients propagated in time. The method was used to study a two-rotor four-bearing system subjected to misalignment.

78-1885

Some Experiments on Instability of Rotors Supported in Fluid-Film Bearings

J. Tonnesen and J.W. Lund
Dept. of Machine Elements, The Technical Univ. of Denmark, 2800 Lyngby, Denmark, J. Mech. Des., Trans. ASME, 100 (1), pp 147-155 (Jan 1978) 20 figs, 11 refs

Key Words: Rotor-bearing systems, Fluid-film bearings, Experimental data, Whirling, Unbalanced mass response

Experiments are conducted on two rotors supported in cylindrical bearings with two axial grooves. The journal position in the bearing is measured by built-in capacitance displacement probes, and the dynamic behavior is monitored by pressure probes. The self-excited whirl at the threshold speed of instability, as well as the influence of unbalance on the whirl frequency, is investigated in detail. By adding damping at the supports, the heavier rotor is stabilized and operated up to 330 Hz. Correlation with theoretical predictions is presented.

78-1886

Finite Element Analysis of Rotor-Bearing Systems with Matrix Reduction

K.E. Rouch
Ph.D. Thesis, Marquette Univ., 263 pp (1977)
UM 7810293

Key Words: Rotor-bearing systems, Finite element technique, Computer programs

This dissertation investigates the application of the finite element technique to dynamic analysis of rotor-bearing systems. In addition, the use of reduced stiffness, mass, and damping matrices to represent the shaft, in place of the complete global stiffness matrices, is explored.

78-1887

Keep Rotor Vibration Under Control

M.L. Adams

Univ. of Akron, Akron, OH, Power, 122 (8), pp 28-29, 65 (Aug 1978) 3 figs, 5 refs

Key Words: Rotor-bearing systems, Subharmonic oscillations, Vibration damping

Rotor subharmonic resonance is a potentially catastrophic vibration phenomenon that could happen in units with fixed-arc journal bearings if a large rotor imbalance occurs, for example, as a result of a turbine blade loss. Properly designed pivoted-pad bearings, unlike fixed-arc bearings, do not lose their damping ability in the subsynchronous frequency range, thus provide effective damping of subharmonic vibration.

78-1888

Critical Speeds, Stability and Response of a Geared Train of Rotors

J.W. Lund

Dept. of Machine Elements, The Technical Univ. of Denmark, Lyngby, Denmark, J. Mech. Des., Trans. ASME, 100 (3), pp 539-535 (July 1978) 9 refs

Key Words: Rotors, Torsional vibration, Lateral vibration, Forced vibration, Free vibration

A method is described for calculating the coupled torsional-lateral vibrations in a geared system of rotors. It considers both forced vibrations, caused by mesh errors or by mass unbalance, and free, damped vibrations whose complex eigenfrequencies define the damped critical speeds and the stability of the rotor system. The rotors, supported in fluid-film bearings, are calculated independently, using the Holzer method for torsional vibrations and the Myklestad-Prohl method for lateral vibrations, after which they are coupled through impedance matching at the gear meshes. The resulting equations are solved for the unknown mesh contact forces, and the roots of the coefficient matrix determinant give the eigenvalues of the system. The method is efficient and readily programmed.

78-1889

Transient Response of a Rotor in Damped Bearings

W.D. Pilkey, J.S. Strenkowski, and P.Y. Chang

Univ. of Virginia, Charlottesville, VA., J. Mech. Des., Trans. ASME, 100 (2), pp 257-265 (Apr 1978) 7 figs, 10 refs

Key Words: Rotors, Transient response, Mathematical models, Modal analysis

In this paper, the transient response of a rotor subjected to a general forcing function is presented. The rotor model permits any number of in-span bearings, which include stiffness, damping, and mass properties. The excitation forces may include distributed loadings along the rotor as well as transient bearing base motion. The response is found by use of a modal analysis that incorporates the damped mode shapes. An illustrative example is presented of a rotor subjected to an initial displacement and a saw-tooth bearing base displacement.

78-1890

Residual-Flexibility Corrections for Transient Modal Rotordynamic Models

D.W. Childs and J.B. Bates, III

Speed Scientific School, Univ. of Louisville, Louisville, KY, J. Mech. Des., Trans. ASME, 100 (2), pp 251-256 (Apr 1978) 8 figs, 10 refs

Key Words: Rotors, Modal analysis, Mathematical models

An extension is presented to a modal formulation for the dynamics of flexible rotors. To date, rotordynamic modal formulations have retained for integration those modes of vibration whose natural frequencies are within or slightly above the operating speed range of the rotor, with higher-order modes simply discarded. In this study, the residual-flexibility technique is employed to account for the "static" contribution of these higher-frequency modes without requiring their integration. The residual-flexibility technique accounts directly for the static contribution of higher frequency modes due to imbalance and external transient loading, and has been adapted to account for reaction forces which are not accounted for by the nominal rotor/bearing stiffness matrix, e.g., bearing damping forces or speed-dependent bearing stiffnesses. The High-Pressure-Oxygen Turbopump of the Space Shuttle Main Engine (SSME) is analyzed.

78-1891

Steady-State Unbalance Response of a Three-Disk Flexible Rotor on Flexible, Damped Supports

R.E. Cunningham

Lewis Res. Center, NASA, Cleveland, OH, J. Mech.

Des. Trans. ASME, 100 (3), pp 563-573 (July 1978) 15 figs, 15 refs

Key Words: Unbalanced mass response, Rotors (machine elements), Squeeze-film dampers

Experimental data are presented for the unbalance response of a flexible, ball bearing supported rotor to speeds above the third lateral bending critical. Values of squeeze film damping coefficients obtained from measured data are compared to theoretical values obtained from short bearing approximation over a frequency range from 5000 to 31,000 cycles/min. Experimental response for an undamped rotor is compared to that of one having oil squeeze film dampers at the bearings.

78-1892

Torsional Frequencies of Multi-Stepped Shafts with Rotors

D.K. Rao

Dept. of Mech. Engrg., Indian Inst. of Tech., Kharagpur, India., Intl. J. Mech. Sci., 20 (7), pp 415-422 (1978) 4 figs, 2 tables, 12 refs

Key Words: Crankshafts, Shafts, Rotors, Inertia effects, Torsional response, Natural frequencies

An exact frequency determinant for natural frequencies of a multi-stepped shaft-rotor system, which includes the effect of shaft inertia, is developed. Frequency equations and modes of a heavy homogeneous engine, and those with one or two additional rotors, are derived using this result. Numerical results indicate that the effect of shaft inertia reduces with an increase in the mode number.

78-1893

Buckling and Vibration of a Rotating Spoke

W.D. Lakin, R. Mathon, and A. Nachman

Dept. of Mathematics, Univ. of Toronto, Toronto, Canada, J. Engr. Math., 12 (3), pp 193-206 (July 1978) 4 figs, 9 refs

Key Words: Wheels, High speed rotors, Eigenvalue problems

The buckling and vibration of the spoke of a rotating wheel is examined. Since the axial load is a function of position closed form solutions for the eigenmodes are prescribed and recourse is made to regular and singular perturbation expansions in terms of several dimensionless parameters appearing in the governing equations. Some numerical results are also included in the interest of completeness.

SELF-EXCITED

(See No. 1867)

SPACECRAFT

(See Nos. 1774, 1775)

TRANSMISSIONS

(Also see No. 1804)

78-1894

Load Distribution in Timing Belts

G. Gerbert, H. Jonsson, U. Persson, and G. Stensson

Machine Elements Div., Lund Tech. Univ., Lund, Sweden, J. Mech. Des., Trans. ASME, 100 (2), pp 208-215 (Apr 1978) 24 figs, 6 refs

Key Words: Belt drives, Mechanical drives

A theory is presented for determining the distribution of the belt tension and the tooth load in timing belts. It appears that the distribution of both loads is of exponential character and one important parameter is the ratio between the spring constant of the tooth and the spring constant of the cord (a nondimensional number). Friction between the belt and the top of the pulley is also considered.

TURBOMACHINERY

78-1895

An Analytic Study of the Energy Dissipation of Turbomachinery Bladed-Disk Assemblies Due to Inter-Shroud Segment Rubbing

R.L. Bielawa

Rotary Wing Technology Group, United Technologies Research Center, East Hartford, CT, J. Mech. Des., Trans. ASME, 100 (2), pp 222-228 (Apr 1978) 9 figs, 3 refs

Key Words: Turbomachinery blades, Shrouds, Energy dissipation, Coulomb friction

A novel computational method is presented for analytically studying the energy dissipative characteristics of turbomachinery bladed-disk assemblies due to inter-shroud segment rubbing. Coulomb friction, as the dissipative mechanism, is utilized in this method with broader generality than that in other similar studies heretofore. The immediate objectives of this study were to obtain an understanding of the general slippage characteristics of the shroud segment interfaces in the presence of both steady normal (to the shroud segment interfaces) lock-up stresses and stresses due to modal vibration, and to incorporate these characteristics in a calculation of the minimum modal deflection required for incipient slipping as well as an estimation of the energy dissipation (damping) due to subsequent rubbing.

78-1896

Unsteady Flows in Turbomachines: A Review of Current Developments

M.F. Platzer
Naval Postgraduate School, Monterey, CA., In: AGARD Unsteady Aerodyn., 28 pp (Feb 1978) N78-22065

Key Words: Turbomachinery, Aerodynamic response, Prediction techniques

The state-of-the-art of turbomachinery unsteady aerodynamics is reviewed with emphasis on theoretical prediction techniques.

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1020	781	342		864	865	1836	127	1538	229
		1322		1334			1647		1799
				1644			1857		

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					215	216			549
						1126			

Myklestad Method

	411								

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	1611		643	644	645	646	647	708	
					1685		927	1718	

Natural Frequencies

310	61	12	103	274	15	106	137	418	189
320	101	512	113	504	105	296	267	438	429
490	411	1462	263	704	125	306	437	1778	569
780	421	1622	283	994	215	686	707	1788	729
1190	731	1892	563	1144	305	706	1287		829
1290	1251		1463	1284	515		1437		1019
1310	1521		1643	1794	556		1777		1339
	1551		1813	1844	1445				1609
					1465				1779
					1785				

Naval Ships

				1514					

Noise Barriers

1240		132	1773		325	1006			
		1832	1843						

Noise Control
use Noise Reduction

Noise Generation

840	1031	192	343	224	225	1306	347	328	689
1870	1381	222	543	344	1235	1476	427	388	869
	1511	1052		354	1236	1506	567	518	969
		1562		384	1395		617	568	1429
		1682		1394	1505		1117	638	
							1347	728	
							1507	1508	

Noise Measurement

350	221	32	1713	604	545	36	817	518	639
680	1011	672	1733	1594	1265	386	1557	818	1079

Noise Measurement (Continued)

1160	1081	822			1715	436		1428	1849
1850	1241	1382				546		1638	1859
	1271	1732				1266		1848	
	1851	1852				1716			
						1736			

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use Sound Level Meters

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			1653						

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610	521	1732	1083			1006	1737	1238	219
840							1847	1738	949
1080									1239
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					1085	1676			

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220	21	132	333	324	355	326	327	328	329
330	331	292	753	494	395	466	387	718	469
720	351	332	1163	674	385	476	427	948	519
750	1161	422	1223	744	475	586	467	1008	589
1010	1201	492	1293	884	495	606	477	1068	719
1030	1511	612	1373	1164	605	806	717	1168	749
1160	1561	652	1393	1474	745	816	727	1478	759
1180	1841	752	1633	1714	855	1086	1007	1508	1009
1560	1871	1012	1663		1005	1166	1087		1069
1840		1042			1085	1206	1167		1539
1870		1052			1165	1396	1207		1559
		1162			1235	1476	1237		1869
		1302			1325	1516	1477		
		1352			1505	1536	1537		
		1842			1515	1666			
		1862			1535				
		1872			1675				
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Noise Source Identification

	751	612	33	34	25	1086	1237		1389
		652	1433	814	385				
				884	605				

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			463	464					

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1170		1182					7		

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	1501				1705				529
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500				1364					

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1310			673	674		286			
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	•1371	1022		184	615	636	337	168	19

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	1581	1192		644	1425	1176	1867	1868	1219
		1372							
		1712							

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1600				1054	1785		1517		409

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					1125				

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920									

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BROWN BOVERI REVIEW Brown Boveri and Co., Ltd. CH-5401, Baden, Switzerland	Brown Boveri Rev.
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MECHANICS RESEARCH AND COMMUNICATIONS Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mech. Res. Comm.
MECHANISM AND MACHINE THEORY Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mech. Mach. Theory
MEMOIRES OF THE FACULTY OF ENGINEERING, KYOTO UNIVERSITY Kyoto University Kyoto, Japan	Mem. Fac. Engr. Kyoto Univ.
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PUBLICATION AND ADDRESS	ABBREVIATION
MTZ MOTORTECHNISCHE ZEITSCHRIFT Frankh'sche Verlagshandlung Pfizerstrasse 5-7 7000 Stuttgart 1, W. Germany	MTZ Motortech. Z.
NAVAL ENGINEERS JOURNAL American Society of Naval Engineers, Inc. Suite 507, Continental Bldg. 1012 - 14th St., N.W. Washington, D.C. 20005	Naval Engr. J.
NOISE CONTROL VIBRATION ISOLATION Trade and Technical Press Ltd. Crown House, Morden Surrey SM4 5EW, UK	Noise Control Vib. Isolation
NOISE CONTROL ENGINEERING P. O. Box 2167 Morristown, NJ 07960	Noise Control Engr.
NORTHEAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS, TRANSACTIONS Bolbec Hall, Newcastle Upon Tyne 1, UK	NE Coast Instn. Engrs. Shipbldrs., Trans.
NUCLEAR ENGINEERING AND DESIGN North Holland Publishing Co. P. O. Box 3489 Amsterdam, The Netherlands	Nucl. Engr. Des.
OIL AND GAS JOURNAL The Petroleum Publishing Co. 211 S. Cheyenne Tulsa, OK 74101	Oil Gas J.
OSAKA UNIVERSITY, TECHNICAL REPORTS Faculty of Technology Osaka University Miyakojima, Osaka, Japan	Osaka Univ., Tech. Rept.
PACKAGE ENGINEERING 5 S. Wabash Ave. Chicago, IL 60603	Package Engr.
PHYSICS TODAY American Institute of Physics, Inc. 335 East 45th St. New York, NY 10017	Physics Today
POWER P. O. Box 521 Hightston, NJ 08520	Power
POWER TRANSMISSION DESIGN Industrial Publishing Co. Division of Pittway Corp. 812 Huron Rd. Cleveland, OH 44113	Power Transm. Des.
PRODUCT ENGINEERING (NEW YORK) McGraw-Hill Book Co. P. O. Box 1622 New York, NY	Product Engr. (NY)
QUARTERLY JOURNAL OF MECHANICS AND APPLIED MATHEMATICS Wm. Dawson & Sons, Ltd. Cannon House Folkestone, Kent, UK	Quart. J. Mech. Appl. Math.

PUBLICATION AND ADDRESS	ABBREVIATION
REVUE ROUMAINE DES SCIENCES TECHNIQUES, SERIE DE MÉCANIQUE APPLIQUEE Editions De L'Academie De La Republique Socialiste de Roumanie 3 Bis Str., Gutenberg, Bucurest, Romania	Rev. Roumaine Sci. Tech., Mécanique
REVIEW OF SCIENTIFIC INSTRUMENTS American Institute of Physics 335 East 45th St. New York, NY 10017	Rev. Scientific Instr.
SAE PREPRINTS Society of Automotive Engineers Two Pennsylvania Plaza New York, NY 10001	SAE Prepr.
SIAM JOURNAL ON APPLIED MATHEMATICS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Appl. Math.
SIAM JOURNAL ON NUMERICAL ANALYSIS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Numer. Anal.
SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, NEW YORK, TRANSACTIONS Society of Naval Architects and Engineers 20th and Northhampton St. Easton, PA 18042	Soc. Naval Arch. Mar. Engr., Trans.
S/V, SOUND AND VIBRATION Acoustic Publications, Inc. 27101 E. Oviat Rd. Bay Village, OH 44140	S/V, Sound Vib.
TECHNISCHES MESSEN - ATM R. Oldenburg Verlag GmbH Rosenheimer Str. 145 8 München 80, W. Germany	Techn. Messen

PUBLICATION AND ADDRESS	ABBREVIATION
TRANSACTIONS OF THE INSTRUMENT SOCIETY OF AMERICA Instrument Society of America 400 Standix St. Pittsburgh, PA 15222	Trans. Instr. Soc. Amer.
TURBOMACHINERY INTERNATIONAL Turbomachinery Publications, Inc. 22 South Smith St. Norwalk, CT 06855	Turbomach. Intl.
VDI ZEITSCHRIFT Verein Deutscher Ingenieur GmbH Postfach 1139, Graf-Recke Str. 84 4 Duesseldorf 1, Germany	VDI Z.
VEHICLE SYSTEMS DYNAMICS Swets and Zeitlinger N.V. 347 B. Herreweg Lisse, The Netherlands	Vehicle Syst. Dyn.
VIBROTECHNIKA Kauno Polytechnikos Institutas Kaunas, Lithuania	Vibrotechnika
WEAR Elsevier Sequoia S.A. P. O. Box 851 1001 Lausanne 1, Switzerland	Wear
ZEITSCHRIFT FÜR ANGEWANDTE MATHEMATIK UND MECHANIK Akademie Verlag GmbH Liepziger Str. 3-4 108 Berlin, Germany	Z. angew. Math. Mech.
ZEITSCHRIFT FÜR FLUGWISSENSCHAFTEN DFVLR D-3300 Braunschweig Flughafen, Postfach 3267 W. Germany	Z. Flugwiss

ANNUAL PROCEEDINGS SCANNED

INTERNATIONAL CONGRESS ON ACOUSTICS, ANNUAL PROCEEDINGS	Intl. Cong. Acoust., Proc.
INSTITUTE OF ENVIRONMENTAL SCIENCES, ANNUAL PROCEEDINGS Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	Inst. Environ. Sci., Proc.
MIDWESTERN CONFERENCE ON SOLID MECHANICS, ANNUAL PROCEEDINGS	Midw. Conf. Solid Mech. Proc.
THE SHOCK AND VIBRATION BULLETIN, UNITED STATES NAVAL RESEARCH LABORATORIES, ANNUAL PROCEEDINGS Shock and Vibration Information Center Naval Research Lab., Code 8404 Washington, D.C. 20375	Shock Vib. Bull., U.S. Naval Res. Lab., Proc.
UNITED STATES CONGRESS ON APPLIED MECHANICS, ANNUAL PROCEEDINGS	U.S. Cong. Appl. Mech., Proc.
WORLD CONGRESS ON APPLIED MECHANICS, ANNUAL PROCEEDINGS	World Cong. Appl. Mech., Proc.

DECEMBER 1978

4-6 15th Annual Meeting of the Society of Engineering Science, Inc., [SES] Gainesville, FL *(Prof. R.L. Sierakowski, Div. of Continuing Education, Univ. of Florida, 2012 W. University Ave., Gainesville, FL 32603)*

10-15 Winter Annual Meeting, [ASME] San Francisco, CA *(ASME Hq.)*

11-14 Truck Meeting, [SAE] Hyatt Regency, Dearborn, MI *(SAE Meetings Dept., 400 Commonwealth Dr., Warrendale, PA 15096)*

FEBRUARY 1979

26-Mar 2 Congress & Exposition, [SAE] Cobo Hall, Detroit, MI *(SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096)*

APRIL 1979

30-May 2 NOISE-CON 79, [INCE] Purdue University, IN *(NOISE-CON 79, 116 Stewart Center, Purdue University, West Lafayette, IN 47907 - Tel. (317) 749-2533)*

30-May 2 Environmental Sciences Meeting, [IES] Seattle, WA *(Dr. Amiram Roffman, Energy Impact Assoc., Inc., P.O. Box 1899, Pittsburg, PA 15230 - Tel. (412) 256-5640)*

30-May 3 1979 Offshore Technology Conference, [ASME] Astrodomain, Houston, TX *(ASME Hq.)*

MAY 1979

20-25 Spring Meeting and Exposition, [SESA] San Francisco, CA *(SESA, 21 Bridge Square, P.O. Box 277, Saugatuck Sta., Westport, CT 06880 - Tel. (203) 227-0829)*

JUNE 1979

12-16 Acoustical Society of America, Spring Meeting, [ASA] Cambridge, MA *(ASA Hq.)*

SEPTEMBER 1979

10-12 ASME Vibrations Conference, [ASME] St. Louis, MO., *(ASME Hq.)*

10-13 Off-Highway Meeting and Exposition, [SAE] MECCA, Milwaukee, WI *(SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096)*

11-14 INTER-NOISE 79, [INCE] Warsaw, Poland *(INTER-NOISE 79, IPPT PAN, ul. Swietokrzyska 21, 00-049 Warsaw, Poland)*

OCTOBER 1979

7-11 Fall Meeting and Workshops, [SESA] Mason, OH *SESA, 21 Bridge Square, P.O. Box 277, Saugatuck Sta., Westport, CT 06880 - Tel. (203) 227-0829)*

NOVEMBER 1979

4-6 Diesel and Gas Engine Power Technical Conference, San Antonio, TX *(ASME Hq.)*

5-8 Truck Meeting, [SAE] Mariott, Ft. Wayne, IN *(SAE Meeting Dept., 400 Commonwealth Dr., Warrendale, PA 15096)*

26-30 Acoustical Society of America, Fall Meeting, [ASA] Salt Lake City, UT *(ASA Hq.)*

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AGMA:	American Gear Manufacturers Association 1330 Mass. Ave., N.W. Washington, D.C.
AHS:	American Helicopter Society 1325 18 St. N.W. Washington, D.C. 20036
AIAA:	American Institute of Aeronautics and Astronautics, 1290 Sixth Ave. New York, NY 10019
AIChE:	American Institute of Chemical Engineers 345 E. 47th St. New York, NY 10017
AREA:	American Railway Engineering Association 59 E. Van Buren St. Chicago, IL 60605
AHS:	American Helicopter Society 30 E. 42nd St. New York, NY 10017
ARPA:	Advanced Research Projects Agency
ASA:	Acoustical Society of America 335 E. 45th St. New York, NY 10017
ASCE:	American Society of Civil Engineers 345 E. 45th St. New York, NY 10017
ASME:	American Society of Mechanical Engineers 345 E. 47th St. New York, NY 10017
ASNT:	American Society for Nondestructive Testing 914 Chicago Ave. Evanston, IL 60202
ASQC:	American Society for Quality Control 161 W. Wisconsin Ave. Milwaukee, WI 53203
ASTM:	American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103
CCCAM:	Chairman, c/o Dept. ME, Univ. Toronto, Toronto 5, Ontario, Canada
ICF:	International Congress on Fracture Tohoku Univ. Sendai, Japan
IEEE:	Institute of Electrical and Electronics Engineers 345 E. 47th St. New York, NY 10017
IES:	Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056
IFToMM:	International Federation for Theory of Machines and Mechanisms, US Council for TMM, c/o Univ. Mass., Dept. ME Amherst, MA 01002
INCE:	Institute of Noise Control Engineering P.O. Box 3206, Arlington Branch Poughkeepsie, NY 12603
ISA:	Instrument Society of America 400 Stanwix St. Pittsburgh, PA 15222
ONR:	Office of Naval Research Code 40084, Dept. Navy Arlington, VA 22217
SAE:	Society of Automotive Engineers 400 Commonwealth Drive Warrendale, PA 15096
SEE:	Society of Environmental Engineers 6 Conduit St. London W1R 9TG, UK
SESA:	Society for Experimental Stress Analysis 21 Bridge Sq. Westport, CT 06880
SNAME:	Society of Naval Architects and Marine Engineers, 74 Trinity Pl. New York, NY 10006
SPE:	Society of Petroleum Engineers 6200 N. Central Expressway Dallas, TX 75206
SVIC:	Shock and Vibration Information Center Naval Research Lab., Code 8404 Washington, D.C. 20375
URSI-USNC:	International Union of Radio Science - US National Committee c/o MIT Lincoln Lab., Lexington, MA 02173

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